THE PHYSIOLOGIC BASIS FOR THERAPEUTIC EXERCISE

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Therapeutic or corrective exercise may be described as the scientific application of bodily movement in treatment of disease or of malfunction. It would appear that the definition of this subject should be more comprehensive. It should carry the implication that somewhat extensive knowledge is necessary to use exercise or bodily motion adequately for therapeutic purposes. Dorland's definition of the term "kinesiology" reads: "The sum of what is known regarding muscular movements, especially hygienic or therapeutical movements." This definition implies that wide basic knowledge is necessary and, were it not that confusion of terms might result, the definition could be taken to apply to therapeutic exercise. One who accepts the responsibility of supervision of therapeutic exercise should have knowledge of mechanical, biochemical and biologic laws in relation to mechanical efficiency and knowledge of physiologic and pathologic-physiologic reactions resulting from malfunction. Such a person must give special study to intricate physiologic processes in their relation to muscular and bony structures and must give consideration to the relationship of malfunction and normal function to organs of the body which otherwise are unaffected.

In general, the teaching of therapeutic exercise, or kinesiology, has been grossly neglected in regard to its use in the field of medicine. The makers of medical curriculums perhaps can be blamed to a certain degree for this neglect. In most medical schools little functional anatomy is taught in relation to the musculoskeletal mechanism. Usually, also, the physiology of muscle is not presented from the standpoint of its general function in regard to motion. Little attempt is made to correlate biophysical and purely physical laws with motion and locomotion. Even though motion is perhaps the most important function of life and the musculoskeletal system therefore constitutes an extremely important part of the body, much less time is spent in teaching the function of this system than is spent in teaching the functions of systems of lesser consequence. The use of corrective exercise has been of much greater interest to the physician practicing physical education and to the militarist than to the average physician. Correlation is lacking between the kinesiologist on the one hand, on the other, the physiologist, the anatomist and the practitioner of medicine. Much of the investigative work has been done by people interested in only one field, such as physical education or physiology of muscle. Great benefits might result from more interest in, and wider knowledge of, the basic principles of corrective exercise. The purpose of this discussion, therefore, is to present a few of those principles which seem to be basic, some of which are well known but little used from a practical standpoint.

Structure of Muscles

Despite the fact that skeletal muscles of man make up about 50 per cent of the body weight, there is less attention paid to this system than to any

other organ or system of the body. An analysis of the importance of the muscles of the skeletal system is locomotion and the ability to carry on the various activities of life will show the medical profession as a whole to be woefully ignorant. Even though the human musculoskeletal system may appear crude as compared with many engineering devices and accomplishments, it is extremely complicated and its functions are not well studied. Each muscle is made up of many thousands of muscle fibers bound together and enclosed by connective tissue. The muscle fibers are cylindrical or prismatic with tapered ends and have a thin elastic wall, within which several nuclei are scattered. Each muscle fiber consists of a fluid portion, the sarcoplasm, and a large number of myofibrillae longitudinally located within the fiber. The myofibrillae, or sarcostyles, are the contractile elements.

Types of Skeletal Muscles

There are two types of skeletal muscle, red and white (pale). The color of muscle depends on the amount of muscle pigment present. The red muscles contain enormous amounts of pigment in the form of granules and are found in position where long-continued contractions are required. The pale fibers are located in organs where rapidity of contraction is essential. Muscles engaged in powerful, slow and repeated movements may contain more than 1 per cent of muscle hemoglobin, which has the property of combining much more readily with oxygen than blood hemoglobin. Muscle hemoglobin furnishes an excellent local store of oxygen. The rapidly acting muscles, such as the breast muscles of birds, contain high concentrations of cytochrome oxidase systems, which are primarily concerned with the activation of molecular oxygen and its utilization in oxidative processes. It is believed that flabby muscles become pale because of the rapid loss of myohemoglobin consequent to paralysis.[1]

Chemical Composition of Muscles

In addition to 80 per cent of water, muscle contains the following: myosin in the fibrils, myogen and myoglobulin in the sarcoplasm, glycogen, some glucose and lactic acid, phosphocreatine and adenosine triphospate.

Chemical Changes in Muscle During Contraction

In spite of the voluminous literature on the chemistry of muscle contraction no crystallization of any opinions or definite conclusions can be made as yet. However, the consensus of most recent evidence suggests the following simplified sequence of chemical events during muscular contraction and recovery. 1. The breakdown of adenosine triphosphate supplies energy to initiate the muscular contraction which is believed to be due, among other things, to a physical alteration of the protein myosin.[2] 2. Breakdown of phosphocreatine supplies the energy required for the resynthesis of adenosine triphosphate. 3. The breakdown of glycogen to lactic acid provides the energy needed for the resynthesis of phosphocreatine. 4. Approximately a fifth of the liberated lactic acid is oxidized to provide energy for the resynthesis of glycogen from the remainder of the lactic acid produced. Oxygen is essential for the last step.

Simple Muscle Contraction

A simple muscle contraction is called a muscle twitch and is produced by the application of a single effective stimulus to a muscle, either through its motor nerve or directly. Such a contraction is composed of three phases

1. Schneider, E. C.: Physiology of Muscular Activity, ed. 2, Philadelphia, W. B. Saunders Company, 1939.

2. Engelhardt, W. A., and Ljubimowa, M. N.: Myosine and Adenosinetriphosphatase, Nature, London **144**:668 (Oct. 14) 1939. Needham, Dorothy M.: The Adenosinetriphosphatase Activity of Myosin Preparations, Biochem. J. **36**:113 (Feb. 6) 1942. Bailey, Kenneth: Myosine and Adenosinetriphosphatase, ibid. **36**:121 (Feb. 6) 1942.

or periods. 1. The latent phase occupies the period between the application of the stimulus and the beginning of contraction. This is the period used by the muscle in overcoming inertia and in initiating the electrical, physical and chemical changes during the process of activation and prior to contraction. 2. The contraction phase is arbitrarily taken to mean the time expended from the beginning of contraction to the beginning of relaxation. 3. The relaxation phase occupies the period from the peak of contraction or beginning of relaxation until relaxation is complete, when the muscle resumes the initial status prior to stimulation.

Are voluntary contractions simple twitches? A careful investigation of voluntary acts reveals them to be compound tetanic rather than simple contractions. In the performance of a voluntary act several muscles act together as a coordinated group. 1. The prime movers, or agonists, are those the contraction of which is primarily responsible for the movement of the part. 2. The antagonists oppose the prime movers. 3. Synergists assist the prime movers and suppress unnecessary movements to a minimum. 4. The fixation muscles, the contraction of which leads to fixation of the neighboring joints, put that part of the body in a position appropriate for the performance of the particular movement.

Types of Muscle Contraction

There are two types of simple muscle contraction. The first type is isotonic contraction, during which a contracting muscle shortens and pulls its insertion toward its origin. Work is done by such an act because the muscle during shortening lifts the weight applied to it. Work equals the weight multiplied by the distance it is lifted. The second type is isometric contraction, during which the muscle cannot shorten but its energy is expended in the form of heat during the increased tension; consequently no work is done by isometrically contracting muscles. Isometric contractions are produced by muscles the origin and insertion of which are firmly fixed and immobile.

The Effects of Systematic Muscular Exercise

Schwartz and associates[3] demonstrated that systematic muscular exercise led to increase of height, weight and vital capacity of adolescent boys. In a study of the influence of exercise on the growth of organs in albino rats, Hatai[4] reported an increase of body weight and organ weights after continued exercise in cages for a period of six months. Born[5] studied a grup of Yale men in their freshman and senior years. He concluded that systematic exercise increases body weight, shoulder breadth, vital capacity, girth and strength of the exercised muscles. Individual bones as well as the entire skeleton are modified by muscular exercise. Regular exercise increased the density of bones. Schneider[1] stated that a man in poor physical condition is easily exhausted by mental and physical exertion while a man in good physical state is mentally alert and physically vigorous and has bright eyes and a healthy complexion. Bainbridge[6] remarked that systematic exercise improves the whole muscular system and increases the range and delicacy of the adjustments of the respiratory and circulatory systems.

The following are some of the more specific effects of systematic muscular exercise on the muscles themselves. The sarcolemma of the muscle

3. Schwartz, Louis: Britten, R. H., and Thompson, L. R.: Studies in Physical Development and Posture: I. The Effect of Exercise on the Physical Condition and Development of Adolescent Boys; II. Bodily Growth with Age; III. Physical Fitness as Reflected in Tests of Muscular Strength, Pub. Health Bull. 179, 1928.
4. Hatai, Shinkishi: On the Influence of Exercise on the Growth of Organs in the Albino Rat, Anat. Rec. 9:647, 1915.
5. Born, F. J.: Quoted by Schneider, E. C.1
6. Bainbridge, F. A.: The Physiology of Muscular Exercise, London, Longmans, Green & Co., 1919.

fiber is toughened and thickened and the amount of connective tissue within the muscles is increased. The size of the muscle increases as the result of increased circulatory and chemical activities during repeated contractions. The number of muscle fibers is not increased, but the individual muscle fibers hypertrophy as a result of exercise. The trophic state of the muscles is much improved by exercise. By training, a great gain in the power of muscle is obtained. Hyde and associates[7] trained the flexors of the second finger of the right hand by ergograph for one month and obtained an increase in the number of contractions from 273 to 918. The distance of lifting the weight had increased from 375 to 1,205 cm. Evidently training improves the quality of contraction. This may be due to more efficient chemical changes making fuel more available, to a greater amount of stored fuel or to a greater abundance of oxygen brought by a more adequate circulation. Training brought about a definite increase of the phosphocreatine content of muscle.[8] Similarly, the muscles of trained legs contained two or three times as much glycogen as those of untrained ones.[9] The muscles of active trained hunting dogs contained more hemoglobin than those of quiet house dogs.[10] Systematic exercise facilitates the transmission of nerve impulses across the motor end-plates and consequently leads to more complete use of all muscle fibers. This makes the use of a muscle in its entirety much easier, and all the fibers can be called into action at once. Precision, endurance and coordination of muscle actions are established by systematic training. These culminate in skill and ease of muscle action as a result of good coordination. A high degree of mechanical efficiency is attained when the efforts of movement are executed at least cost. This is the basis of muscular training and reconditioning used so extensively in Veterans Administration and Army Centers and also makes an important aspect of De Lorme's[11] graduated exercise.

Repeatedly activated muscles have a very efficient blood supply. Either new capillaries appear, or hitherto unused capillaries open up. Krogh[12] found a great increase of the number of patent capillaries in activated muscles. This insures a better circulation and supply of oxygen and a more efficient disposal of wastes. The great endurance resulting from systematic training is due to efficient and coordinated development of the respiratory, circulatory and nervous systems consequent to repeated organized action. Systematic exercise increases the skill and efficiency of the muscles at a much smaller consumption of oxygen as compared with untrained muscles. Low resistance and frequent repetition of exercise increase endurance but not power. Increased resistance and infrequent repetition of exercise increase power and endurance and probably lead to hypertrophy of the muscles. Isometric exercise without resistance — for example, quadriceps setting — may not increase power materially but it probably enables a muscle to perform a greater number of contractions at one time.

It is important to remember that heavy resistance exercise on one side has a definite influence on the muscles of the contralateral side. This was shown by the work of Hellebrandt, who found that unilateral heavy resistance exercise which rapidly augments the strength and staying power of the ipsilateral limb has a strikingly similar concomitant effect on the contralateral

7. Hyde, I. H.; Root, C. B., and Curl, H.: A Comparison of the Effects of Breakfast, of No Breakfast and of Caffeine on Work in an Athlete and a Non-Athlete, Am. J. Physiol. 43:371 (June 1) 1917.
8. Palladin, Alexander. and Ferdmann, D.: Ueber den Einfluss des Trainings der Muskeln auf ihren Kreatingehalt, Ztschr. f. physiol. Chem. 174:284 (Mar.), 1928.
9. Embden, G., and Habs, H.: Beitrag zur Lehre vom Muskeltraining, Skandinav. Arch. f. Physiol. 49:122 (Nov.) 1926.
10. Whipple, G. H.: The Hemoglobin of Striated Muscle: I. Variations Due to Age and Exercise, Am. J. Physiol. 76:693 (May) 1926.
11. De Lorme, T. L.: Heavy Resistance Exercises, Arch. Phys. Med. 27:607 (Oct.) 1946.
12. Krogh, August: The Anatomy and Physiology of Capillaries, ed. 2, New Haven, Conn., Yale University Press, 1929.

unpracticed limb. Her conclusions were as follows:

1. Improvement in the functional capacity of the symmetrical muscle groups of the unexercised side is usually less marked than that resulting from direct practice.
2. The determining causal factor in so-called cross education is the severity of the effort evoking the response, rather than the duration of exercise.
3. Cross education is a misnomer if it presupposes that the unpracticed limb is unexercised.
4. It is suggested that cross education has a dual genesis in the diffusion of motor impulses to the unpracticed side by way of irradiation and tonic postural reflexes, arising in and on the limbs. Nothing in this study indicates whether or not muscle groups of the contralateral limb symmetrical to those exercised on the ipsilateral side, exhibit higher degrees of reflex isometric tension than other anatomical parts participating in the adaptive reflex figure.
5. It is suggested that cross education may serve as a useful therapeutic tool where volitional control is unilaterally defective or where contralateral muscle groups are rendered temporarily inaccessible through immobilization.

Oxygen Debt

Muscular activity creates an extra demand for oxygen. Man has no extra supply or store of oxygen. As Schneider aptly put it: "man practically lives a hand-to-mouth existence as far as his oxygen supply is concerned. His blood carries the only reserve of this gas that there is in the body." The total quantity of oxygen carried in the blood amounts to about 1,300 cc. The basal oxygen requirement of an average adult is about 250 cc. per minute. On severe exertion this may be increased about twenty times. Consequently, the body must be provided at all times with an abundant supply of oxygen if normal activity is to be maintained for some time. When muscle is exercised in the presence of oxygen, lactic acid does not accumulate because the liberated lactic acid is oxidatively synthesized to glycogen during the process. However, in the absence of oxygen lactic acid accumulates, waste products pile up, fatigue progressively sets in and the muscle becomes inexcitable. Normally oxygen is not used in the initial process of contraction; it is used mostly in the recovery processes. Therefore it is helpful to develop muscles of the type containing larger amounts of muscle hemoglobin, especially in severe disability, in which increased capacity for power and endurance in the remaining groups of normal muscle is necessary for locomotion.

In moderate, long-continued exercise a "steady state" develops, during which equilibrium is established between the processes of breakdown and recovery. However, in exceedingly severe bouts of exercise, such as the 100 yard dash, an equilibrium between breakdown and recovery cannot be maintained but recovery occurs after the event is over. Exceedingly violent exercise cannot be maintained long because lactic acid and other products accumulate to maximal level and severe fatigue sets in after a certain amount of lactic acid (about 0.3 per cent) accumulates. The muscles become incapable of performing under such circumstances.

The increased need for oxygen in exercise is due to the following factors: 1. As muscular exercise goes on, decomposition of the energy-producing chemicals occurs at a greatly increased rate. The utilization of oxygen, which removes these decomposed products, also increases. 2. The temperature of activated muscles rises, and along with it the speed of the chemical processes increases. Heat is produced by muscle during the breakdown as well as during the recovery processes. 3. During exercise both the respiration and the circulation are speeded up to meet the increased demand for oxygen by the muscles. If the exercise is moderate, a person reaches a uniform rate of oxygen intake which furnishes the energy required for resyn-

thesis. A "steady state" sets in, and the accumulation of fatigue products is prevented by immediate resynthesis. If the exercise is severe, a state of oxygen debt supervenes. A good athlete can run the 100 yards without breathing; and, after the run is over, he spends some time getting enough oxygen to provide sufficient energy for resynthesis of the chemicals that were decomposed in his muscles during the exertion. At the best accomplishment of one's respiratory and circulatory systems, one may not be able to take in more than 5 liters of oxygen per minute; yet in severe forms of exercise more than 22 liters of oxygen may be required to provide the energy used in one minute. Consequently, an oxygen debt is incurred. Oxygen debt is determined by measuring the amount of oxygen used in excess of the resting metabolism during the period beginning with the end of exercise and continuing until recovery is complete. The oxygen debt could amount to about 19 liters.

Two mechanisms for contracting oxygen debt have been demonstrated:[13] alactacid mechanism and lactacid mechanism. In the alactacid mechanism no lactic acid accumulates. The alactacid oxygen debt is paid at a much faster rate than the lactacid debt. There is evidence indicating that about half of the alactacid debt is paid in about half a minute while the removal of the lactacid debt is at least fifteen times slower. The lactic acid formed in muscle during exercise diffuses into the blood, is removed by the liver and is converted into glucose. A part of the lactic acid is oxidized to provide the energy needed for conversion of the rest to glucose.

Factors Determining the Rate of Oxygen Intake

1. *Ventilation of the Lungs.* — The amount of air taken in per minute increases with the increase of the exertion. Deep breathing slightly increases the partial pressure of oxygen in the lungs and consequently the rate of passage of oxygen into the blood is also slightly increased.

2. *Oxygen Capacity of the Blood.* — The hemoglobin content of the blood is the determining factor. Each gram of hemoglobin can carry 1.34 cc. of oxygen. The normal concentration of hemoglobin is about 15 Gm. per 100 cc. of blood.

Muscle Fatigue

Fatigue is a state occurring at the end of a period of repeated activity during which a great reduction occurs in the capacity of muscle to respond to stimulation. It is a sign of depletion of available reserves and accumulation of waste products. Muscular fatigue is a transient reduction of working power of the muscle from which recovery takes place after a period of rest. The ability to recover after rest differentiates fatigue from exhaustion, from which recovery either fails to occur or occurs slowly. During fatigue, irritability, contractility and conductivity of muscle are depressed. The latent period is prolonged, and contraction and relaxation become slow.

Schneider stated that in the ordinary performance of long-continued exercise three stages are experienced. During the first stage the ability to do work gradually increases but the performance is at first distinctly uphill. If the work is continued, however, it becomes easier and the state of being "warmed up" supervenes. This brings about the second stage, during which the output of work has reached a plateau at a high level. Eventually the work becomes harder and the third stage sets in, during which power and output gradually decrease.

13. Margaria, R.; Edwards, H. T., and Dill, D. B.: Possible Mechanisms of Contracting and Paying Oxygen Debt and Rôle of Lactic Acid in Muscular Contraction, Am. J. Physiol. **106**:689 (Dec.) 1933.

Seat of Fatigue

Two types of fatigue are recognized, one arising within the nervous system and the other within the muscles themselves. In the laboratory the following experiment is performed to demonstrate the seat of fatigue. In a decerebrate frog the spinal cord is exposed and stimulated electrically at a certain fixed rate until the muscles fail to respond. The sciatic nerve is then immediately stimulated with the same strength and frequency. The muscles that failed to respond to stimulation through the spinal cord give effective responses to the stimuli applied to the nerve. However, before long these same muscles will fail to respond to the stimuli through the nerve, but, if the same stimuli are applied directly to the muscle immediately after it has failed to respond to stimulation of the nerve, the muscle will again respond effectively for some time before it finally fails to respond even to the directly applied stimuli. Such experiments led to the conclusion that the synapses in the central nervous system are most susceptible to fatigue. The second seat of fatigue is the myoneural junction (motor end-plate) and last is the muscle itself. Nerve fibers themselves cannot be fatigued.

Recent experimental work indicates that direct electrical stimulation maintains muscle substance in denervated muscles.[14] This contradicts the old clinical concept that exercise of paralyzed muscles leads to further damage. Clinical observations on patients who have peripheral nerve injuries of various types give supportive evidence to the facts obtained from experimental work — namely, that early and systematic stimulation of paralyzed muscles tends to prevent atrophy rather than to produce damage. From these observations it can be concluded that direct electrical stimulation of completely paralyzed muscles and systematic voluntary exercise of partially paralyzed muscles are conducive to maintenance of muscle substance and even hypertrophy rather than damage of the involved muscles.

Causes of Fatigue

Fatigue is chemical in character and is caused by activity which involves expenditure of energy. It may result from depletion or nonavailability of energy stores or from the accumulation of end products of metabolism. There may also occur a breakdown of homeostasis or a serious alteration of the physicochemical state. Reduction or depletion of available energy is the most valid explanation. The administration of nutritive elements, such as sugar, delays the onset of fatigue. Low blood sugar levels were found in exhausted marathon runners. Reduction of the oxygen supply is a highly efficient means of hastening the onset of fatigue. Lactic acid, carbon dioxide and acid phosphate were the chief waste products accumulated during fatigue. Excessive loss of chlorides and weakening of the synthetic capacity of muscles are additional causes of fatigue.

Basic Principles Involved in Muscular Action

Muscles are useful because they are able to produce motion through tension between their various attachments. Therefore, two general factors exist in regard to muscular physiology. One is the mechanism by which muscle fibers are able to produce tension; the other is the means by which muscular tension is applied in order to perform satisfactory motion. Muscular power would be of no value unless the means were present by which this tension could become effective in the organism.

14. Wehrmacher, W. H.; Thomson, J. D., and Hines, H. M.: Effects of Electrical Stimulation on Denervated Skeletal Muscle, Arch. Phys. Med. **26**:261 (May) 1945. Hines, H. M.; Thomson, J. D., and Lazere, B.: Physiologic Basis for Treatment of Paralyzed Muscle, Arch. Phys. Therapy **24**:69; 99 (Feb.) 1943. Fischer, Ernst: The Effect of Faradic and Galvanic Stimulation Upon the Course of Atrophy in Denervated Skeletal Muscles, Am. J. Physiol. **127**:605 (Nov. 1) 1939. Solandt, D. Y.; DeLury, D. B., and Hunter, John: Effect of Electrical Stimulation on Atrophy of Denervated Skeletal Muscle, Arch. Neurol. & Psychiat. **49**:802 (June) 1943. Gutmann, E., and Guttmann, L.: The Effect of Galvanic Exercise on Denervated and Re-Innervated Muscles in the Rabbit, ibid. **7**:7 (Jan.-Apr.) 1944.

Muscular tension is made useful through its action on a series of levers provided by the rigid skeletal structures. The ability to increase the power of applied force is the main function of the series of levers. However, in the body the levers not only increase the power but, probably of more importance, produce rotation. This is essential because locomotion of a jointed body is produced by rotary forces as well as actual power.

Many influences affect the lever system, such as gravitational forces, forces of acceleration and deceleration and the external forces related to gravity that are necessary to maintain equilibrium. Regulation of motion must take place through muscular action. This is done in three ways:[15] "(1) When movement is not desirable the muscles must exert force which will balance the other forces present, so that rotation of levers does not take place. (2) When movement does take place, the muscles must be able not only to accelerate movement, but also to decelerate movements. (3) Muscles must be able to regulate the energy of the system by contributing energy from the chemical forces or removing energy by dissipation into heat as occasion requires."

Stabilization of Joints. — Another important function of muscular action is that of stabilization of the joints, or the so-called invisible motions. Stabilization is dependent on the fact that the muscles are so attached that they produce a pull almost parallel to the long axis of bones. This produces a strong component of force in this direction, which tightens the joint capsule and pulls the articular surfaces together, giving much greater stability of joints. These invisible motions are produced before actual rotary motion takes place. It has been pointed out by Steindler[16] that stabilization is a static function of motor power and is as important as, if not more important than, the rotary action of muscular pull. Subluxation of joints would occur and many more strains and stresses would be present in the joints if such stabilizing action were not present. Deformities are brought about by lack of such action in certain cases of muscular paralysis and weakness. Examples of these are subluxation of the humerus in the presence of paralysis of the deltoid muscles, "back knee" deformity in cases of paralysis of the quadriceps muscle and possibly deformities of the feet which occur when the muscles which support the arches of the feet are weak, although this is questioned by some authorities.

Increasing the Angle of Pull. — Topographic adaptation is an important element in relation to muscular action. In nearly every instance, the muscles are almost parallel to the axis of the bones to which they are attached. Therefore, certain provisions are made for increasing the angle of pull and thereby the rotary action. If these factors were not present, the parallel axis of pull would, in some instances, produce a "dead center" and would interfere with rotary motion. Examples of such adaptation are the ball-shaped ends of bones, which cause deflection of tendons away from the joints, thus producing a greater rotary component of pull. Specific examples are the following: 1. The gastrocnemius and the hamstring muscles are deflected away from the knee joint by the prominent ball-like surface of the condyle of the femur. 2. The quadriceps muscle is attached in the patella; thus the patella deflects the tendon away from the knee joint, giving the muscle a greater rotary force. In the fingers, the tendons of the flexor digitorum profundus and the flexor digitorum sublimis run almost parallel to the bones but the attachment of the flexor digitorum sublimis is divided at the base of the proximal phalanx of each of the four fingers. The tendons

15. Elftman, Herbert: Action of Muscles in Body, Biol. Symposia, vol. 3, Lancaster, Pa. The Jaques Cattell Press, 1941, pp. 191-209.

16. Steindler, Arthur: Mechanics of Normal and Pathological Locomotion in Man, Springfield, Ill., Charles C. Thomas, Publisher, 1935, pp. 32, 65, 74, 77, 100 and 196.

of the flexor digitorum profundus run to the distal phalanges of the fingers, having passed through the tendons of the flexor digitorum sublimis muscle. When the flexor digitorum sublimis contracts, the tendons of the flexor digitorum profundus are pulled away from the bones, thereby giving the tendons greater rotary force on the distal phalanges of the fingers. These elements are important if any change of alinement is made by surgical procedures.

Elasticity and Extensibility. — The elasticity of muscles follows Hooke's law to a certain degree — that is, muscles increase in length in direct proportion to the extending force. Extensibility of a muscle means that when it is placed on stretch it is capable of being extended. Elasticity and extensibility of muscle are essential for several reasons — namely, they allow smoothness of motion; they tend to relieve the sudden impact consequent on overcoming the inertia of load, and thus they allow greater tension, increase the power of muscles and prevent rupture.

The point at which rupture of muscle will occur has not been fully investigated. However, it is known that long before the breaking point has been reached the extending force will cause structural damage. It also is known that persistent stretching of a muscle will produce fibrous degeneration and that sudden stretching may tear individual muscle fibers. Therefore, sudden, forced motion should be avoided in therapeutic exercise. Careful appraisal of elasticity and extensibility of muscles under treatment should be made. It should be kept in mind that decreased extensibility and elasticity do occur and that there are limitations beyond which muscles cannot be stretched safely. It is considered better technic to attempt to increase the power of the muscle that opposes the shortened or spastic muscle and to use this muscle to produce active stretching of the involved muscle. This decreases the possibility of producing muscular spasms, tears and possibly the permanent damage that sometimes results from forced, passive stretching.

Contractility. — The contractility of muscles is a complex phenomenon, and space does not allow detailed discussion. However, it has been known for centuries that the lifting height of muscles is greater the greater the length of the fibers. The ability of muscle to lengthen has been variously estimated, and, in general, it is known that there is a great deal of difference in the contraction length of fibers of the same muscle. A muscular contraction is most powerful when the muscle is at its maximal length, since its tension is greatest in this position. Tension becomes markedly reduced as contraction progresses. Thus the power of muscle is greatly decreased when the muscle is most fully contracted and shortened. When partial contraction of a muscle has given it increased leverage, this gain is offset by the loss of tension.

In performing reeducation exercises or in testing for strength of a muscle, it is desirable to place the muscle in a situation wherein its full power or greatest strength can be ascertained. There are two methods by which this can be done. First, the angle of pull can be increased by flexion of the joint which is moved by the muscle. This releases tension but increases leverage. To state the reverse of the point of view expressed at the close of the preceding paragraph, the loss of power occasioned by decrease of tension is compensated by the flexion. Sometimes, a second joint which the muscle crosses can be extended in order to increase the tension lost by flexion of the first joint. An example of this is the movement of the leg on the knee. The hamstring muscles are at a greater advantage in leverage when the knee is partially flexed than when it is extended. If the knee alone is flexed, these muscles lose tension and thereby power. If the hip is flexed, then the hamstring muscles are put under tension and the advantages of both increased

leverage and tension are obtained. This mechanism comes into play primarily in respect to muscles which serve more than one joint and is of considerable importance whenever rehabilitation of such muscles is attempted. These so-called pluriarticular muscles will be considered again when coordination is discussed. Monarticular muscles are exercised usually in their resting length.

Some believe that the degree of muscular tension is governed by the degree of innervation.[17] The inhibitory centers tone down the state of contraction to an optimum which changes with the dynamic requirements. Until comparatively recent times, not much information could be obtained as to how much innervation was necessary to each muscular contraction. However, this has been studied to a certain extent, since it has been possible to measure the action current.[16] It is known that graded responses are brought about by varying the number of muscle fibers, or the units of the muscles, which are involved in response at any one time.[17a] The studies of Adrian and Bronk[18] indicated that the rate of discharge of impulses from the central nervous system is highly variable in voluntary contractions. Frequently contractions began at a stimulation rate of 5 or 6 per second but gradually increased in magnitude as the contractions became stronger. They ultimately reached a rate of 30 or 40 per second, sometimes as high as 50 per second in powerful responses. Therefore, graduation of responses is affected by variation in the rate of discharge of impulses from the centrol nervous system.

As compared with slow motion, rapid motion uses a great deal more energy to accomplish much less work. Most muscular action is done at a certain optimal rate at which it can accomplish the most without fatigue. Undoubtedly, this optimal rate varies with the condition of muscular power and with the neuromotor elements which control it.

From the standpoint of clinical application, exercises should be taken or given slowly in nearly all instances, because (1) if innervation is poor only a few muscle fibers may be activated and fatigue will appear quickly even with slow motion but rapid movement further increases the possibility of fatigue; (2) in muscles weakened from causes other than lesions of the nervous system, slow, mild motion should be used gradually to strengthen the muscle. Rapid, maximal motion quickly fatigues muscle and may be harmful owing to inability of the muscle to recover from the chemical products of fatigue. In certain conditions such as those in which there is articular involvement (inflammatory or traumatic) other factors, aside from those involving the muscle, must be taken into consideration in relation to speed and intensity of motion. Sudden, jerky or rapid movements in these instances tend to produce more damage or trauma to already involved joints, which, in turn, produces more muscular spasm and loss of muscular power, elasticity and contractility. Thus a vicious cycle results.

Tone. — Muscular tone is the quality whereby muscle remains under sustained tension. Tension is necessary to maximal power of muscular contraction. Tone is necessary to maximal efficiency of the contraction, and, therefore, it is important in relation to economy of energy. Likewise, tone is of importance with respect to adequate stabilization of the skeletal system.

From a clinical standpoint, the importance of maintaining muscular tone has been long recognized. Lack of tone in muscles can be responsible for loss of tension and reduced power, although tone is not identical with power. Occasionally, because of lack of tone, a fairly strong muscle is not adequate

17. (*a*) Gould, A. G., and Dye, J. A.: Exercise and Its Physiology, New York, A. S. Barnes & Company, 1932, pp. 23, 25, 73, 76 and 77. (*b*) Steindler.[16]

18. Adrian, E. D., and Bronk, D. W.: The Discharge of Impulses in Motor Nerve Fibers: Part II. The Frequency of Discharge in Reflex and Voluntary Contractions, J. Physiol. 67:119 (Mar. 20) 1929.

to the task of holding a limb in a given position. Lack of tone may add to the instability of joints and may increase the chances of injury or sprain, because muscles are as important as ligaments and other joint structures in stabilization of joints. Therefore, increased length and relaxation of muscles, through loss of tone and tension, may affect materially this stabilization of joints.

Exercise can be used to increase the tone of muscles. Such exercise should be of the isometric type — that is, a tightening of the muscle without producing motion or holding of the joint and its movable part in a given position against resistance.[19]

Coordination. — Coordination of muscular action is complicated not only from a neuromuscular standpoint, which will not be discussed to any extent here, but also from a mechanical standpoint. In relation to the neuromuscular mechanism, it must be pointed out that in order to have coordination and smoothness of motion, the reflex arcs must be intact. "The maintenance of posture is an example of the nicety of adjustment between various parts of the body to fit the new position."

Reciprocal innervation and inhibition of muscles are most important in producing coordination. Reciprocal innervation means that when a voluntary or reflex contraction occurs, as in the biceps muscle, it is accompanied by relaxation of its antagonist, the triceps muscle.[20] The inhibition is not brought about through specific inhibiting nerves, as are cardiac and intestinal inhibitions, but its due to cessation of excitations and impulses along the motor neurons.[20] The mechanical elements entering into coordination are not often stressed. However, as has been pointed out aptly by Steindler,[16] considering coordination from a mechanical standpoint, elementary knowledge of the lever system and, one might add, of neurologic control, does not suffice. It is necessary to consider not only the effect of muscle on its own lever arm but also its effect on neighboring and even remote articulations. The stresses, strains and resistances due to gravity and inertia must be taken into consideration as they affect tension and rotary motion. Complicated problems arise in relation to action of the pluriarticular muscles and their effect on more than one articulation. The meaning of the functional efficiency of a pluriarticular muscle can be grasped only when the action and reaction of the whole limb or body as a mechanical unit are taken into consideration.

Only fairly recently has the plural action of single muscles been considered. Most books on anatomy give only one principal action of a muscle. But "there is hardly any muscle which has an unchangeable motor effect in respect to any joint and it will appear consistently . . . that muscle function changes constantly with the position of the muscle in relation to the three orientation planes. As the function of the muscle changes so changes also that [the function] of the antagonist, being never quite the same in different positions; and this change is both qualitative and quantitative. . . ."[16] In numerous instances the primary function of a muscle in respect to a certain plane gradually changes to the reversed motor effect.

The mechanical variations and multiple actions of muscles relative to coordination cannot be discussed in their entirety in a paper of this type. However, certain characteristics relative to these variations and actions, which may be of clinical value and which might create greater interest in further observation, will be mentioned.

Several types of contraction relative to muscular function should be re-

19. Kraus, Hans: Behandlung akuter Muskelhärten, Wien. klin. Wchnschr. 50:1356 (Oct.) 1937.
20. Best, C. H., and Taylor, N. B.: The Physiological Basis of Medical Practice, ed. 2, Baltimore, The Williams & Wilkins Company, 1939, pp. 1323-1324.

viewed. When contraction of a muscle produces decrease of distance between its origin and insertion, the process is known as a "shortening contraction" or a "concentric contraction." This type of contraction overcomes gravity or resistance and produces motion. During this contraction, either both ends of the muscle will move toward each other or, if one attachment of the muscle is fixed, the other attachment will be moved. This action then can have various effects, the origin of a muscle can be moved or, reversing the movements of the parts, its insertion can be moved. Examples of this action can be seen in relation to the anterior tibial muscle. When the origin of this muscle (the tibia) is fixed, the foot is moved in relation to the leg. If the foot is stabilized, as it is when a person is standing, the leg is moved or stabilized. Again, the gastrocnemius may bring about plantar flexion of the foot or, if the foot is fixed, action of the muscle is on its origin (the femur) and the tendency is to flexion of the thigh.

Another type of contraction is known as "eccentric," or "lengthening," contraction. In this type of contraction outside forces cause the movement and the muscle regulates the speed at which the outside force may move the part. The muscular force constitutes a braking action. An example would be that of the flexed forearm being pulled down by the weight of the forearm and hand. The triceps does not act at all to produce extension, but the biceps brachii increases its length while, nevertheless, braking the speed of movement. This action is of considerable significance in coordination and in regulation of speed of a movement in which the part already in motion may exert considerable momentum.

If a muscle acts "to take up slack" but does not produce motion, the action is known as a "static contraction" and is primarily stabilizing in its effect. Other examples of such action are numerous in the coordinated muscular movement of the body; for instance, the stabilizing contraction of the gluteus muscles to prevent pelvic tilt in the process of taking a step, or contraction of the extensor muscles of the wrist in order to stabilize the hand when flexion of the fingers occurs.

Another muscular action which is of importance in relation to coordination is that known as "guiding action." During this action, muscle does not actually perform motion but controls the direction of motion. An example of this is the following: When the gastrocenmius and soleus muscles bring about plantar flexion of the foot, the tibialis anterior and peroneal muscles guide the inversion and eversion. It is obvious that there are many other instances of such action of muscle. These muscles which exert guiding action are in fine balance with each other and with the prime movers in regard to direction.

Another action of muscles is that necessary for maintenance of balance. This has to do with action around weight-bearing joints. Essentially, it consists of a give-and-take action, in which minute eccentric and concentric contractions of muscles restore balance when imbalance begins or has occurred.[21] These minute contractions control the invisible motions that were mentioned in the discussion of stabilization.

As already has become evident, there are two general groups of muscles in the body relative to the joints: the pluriarticular muscles and the monarticular muscles. In general, these groups act similarly in relation to the several actions of muscles — that is, they act concentrically, eccentrically or statically. Any of them may produce a stabilizing action, may assist in balancing or may exert a guiding action.

Pluriarticular muscles become important as economizers of energy, espe-

21. Brunnström, Signe: The Changing Conception of Posture: Methods of Dealing with Faulty Posture, Physiotherapy Rev. 20:79 (Mar.-Apr.) 1940.

cially in relation to the synergistic action of monarticular muscles. The more joints a pluriarticular muscle covers, the more the possibilities of its action there may be. Theoretically, when a muscle passes over several joints, it may act on any one of the joints, on all of them or on any combination of joints. Therefore, it cannot properly be said that a pluriarticular muscle has a primary action and secondarily produces other definite actions. These so-called secondary actions will depend on the circumstances at the time of the motion in relation to the gravitational pull, the rotational components and the various parts of the body which may be fixed. For instance, when the biceps brachii contracts, if the shoulder is fixed, the elbow flexes and combined with this flexion is forward flexion and abduction of the shoulder. Another example is that in which the pelvis is fixed when one is rising from a sitting position. The ball of the foot is fixed on the ground, the knee is slightly flexed and contraction of the hamstring muscles produces extension of the knee and dorsiflexion of the foot.

The concurrent and countercurrent shifts of the biarticular muscles, as pointed out by Baeyer,[22] have been studied particularly in relation to gait. Concurrent shifts of muscles are described as parallel actions between two groups of biarticular muscles in which neither group changes its length. An example of this is when the hip and knee are being flexed at the same time. The hamstring muscles in this instance move in a parallel manner, or concurrently, and in cooperation with the rectus femoris muscle. As the knee flexes with flexion of the hip, the origin and insertion of the rectus femoris move in the same direction — that is, they both move downward. None of the muscles under consideration change in length. Countercurrent shift, on the other hand, is illustrated when the hip is flexed and the knee extended. The origins of the hamstring muscles move upward, but their insertions move downward, whereas the origin and insertion of the rectus femoris are moving toward each other. The tension of the rectus femoris will be lessened because the origin and insertion have become approximated. Also, the hamstring muscles offer resistance to extension of the thigh when flexion of this member has reached 90 degrees or less; this resistance also hinders extension of the knee. It can be seen, therefore, that concurrent actions of these biarticular muscles are more efficient than countercurrent actions.

The action of monarticular muscles is not so intricate as that of pluriarticular muscles but, as has been pointed out, they have all the general actions that the pluriarticular muscles have. Monarticular muscles frequently act in assistance of the pluriarticular muscles; that is, because of certain positions and because of loss of tension such as occurs in countercurrent action of pluriarticular muscles, associated monarticular muscles may provide added power to finish the required motion. Examples of these combinations are the gastrocnemius with the soleus, the hamstrings with the short head of the biceps and the rectus femoris with the vasti.

In some instances, a muscle of lesser magnitude but of greater leverage may initiate the primary movement of a more powerful muscle. This is seen when the angle of pull of the powerful muscle is such that at full length it may be near dead center. Examples are the action of the iliopsoas and sartorius muscles. With the hip fully extended, the iliopsoas cannot produce great flexor power because it is inserted too near the long axis of the bone. This gives great stabilizing power, but, in order to produce rotary power, the sartorius, with its greater angle of pull, initiates flexion of the thigh. When a small angle of flexion has been produced the iliopsoas, having great shortening power, becomes a powerful flexor of the hip. This explains

22. Baeyer, H. V.: Die Synhapsis in der allgemeinen Gleidermechanik, Report of the Second International Orthopedic Congress, London, 1933.

why, in the absence of part of the flexors of the hip, particularly of the sartorius, the iliopsoas does not work well even though seemingly it is powerful and even if the hip is extended so that the iliopsoas is stretched.

Only a few of the intricacies of the mechanics of muscular action and coordination have been cited. Perhaps sufficient material has been presented, however, to indicate the necessity of considerable study of this subject by the physician and the technician.

PATTERNS OF MUSCULAR ACTIVITY IN MAN*

ERNST GELLHORN, M.D., Ph.D.

MINNEAPOLIS

Whereas under conditions of slight movement only the agonist, or agonist and antagonist (either in the form of reciprocal inhibition or of co-activity[1]), are involved, somewhat stronger movements call into action associated muscles. This phenomenon, well known from the study of fatigue, can be easily demonstrated even in nonfatigued muscles. A systematic study of such patterns of activity illustrated in the relation of biceps and triceps muscles to the activity of the wrist muscles is presented. This investigation was carried out at first as a preliminary to the study of innervation patterns in patients with poliomyelitis. However, the results seem to be of sufficient interest as a contribution to the understanding of patterns of movements in man to warrant their separate publication.

Methods

The experiments were performed on 12 persons (aged 20 to 30) whose action potentials were recorded by means of surface electrodes. These electrodes consisted of copper plates (about 1 cm. in diameter) and were placed at a separation of 1 to 2 cm. over the muscle. The arm was stretched forward in horizontal position, and the forearm was well fixed between several clamps and bars.[2] The elbow angle was about 130 degrees. The experimental subjects were requested to flex or to extend the wrist when the hand was prone or supine. The activity of biceps, triceps, flexor carpi radialis and extensor carpi radialis muscles were simultaneously recorded by means of a push-pull condenser coupled amplifier and an Offner inkwriter. The movements were nearly isometric and were carried out against springs of varying strength, the tension being recorded on a kymograph.

Results

The four types of wrist movement involving flexion and extension with the hand pronated or supinated will be discussed separately.

I. *Flexion of Wrist with Hand Pronated.* — Whereas only the flexor carpi radialis muscle was activated in very slight flexion of the wrist, it was noted that with greater exertion the triceps muscle responded also. Figure 1 is a typical example showing that strong flexion of the wrist is associated with a distinct contraction of the triceps which occurs simultaneously with that of the flexor carpi radialis but is of a lesser degree. The fact that the triceps is activated although no action potentials are obtained from the extensor

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* Aided by a grant from the National Foundation for Infantile Paralysis.

1. (*a*) Bosma, J. F., and Gellhorn, E.: Unpublished observations. (*b*) Compare also their study on the effects of stimulation of the motor cortex on reciprocal innervation and co-innervation, J. Neurophysiol. 9:263, 1946.

2. However, as noted later, similar results were obtained without fixation.

carpi radialis shows that the triceps is called into action without fixation of the wrist. However, with strong flexion of the wrist the extensor carpi radialis may likewise show potentials, but individual differences are marked in this respect. Thus, subject S (fig. 2) shows co-activity of the extensor carpi radialis with a tension of 6 pounds, whereas subject B (fig. 1) does not activate this muscle when the flexor exerts a tension of 9 pounds.

As the degree of effort increases, additional muscles are activated. Subject P shows slight action potentials in the biceps when a flexion of the wrist (9 pounds tension) is performed (fig. 3), but such activity is absent in the same subject with movements involving lesser tension. The degree of activity of the biceps under these conditions is only a small fraction of that seen in the triceps muscle (figs. 3 and 4).

It was mentioned that the extensor carpi radialis may or may not be activated during the flexion of the wrist with the hand pronated (figs. 1 and 2). Since in both cases the biceps may remain inactive and since the contraction of the triceps is apparently independent of the appearance of action

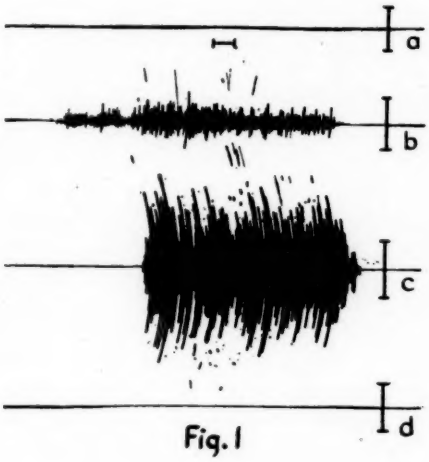


Fig. 1

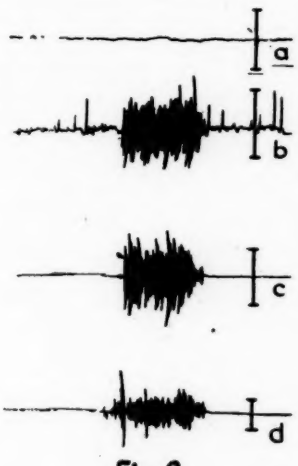


Fig. 2

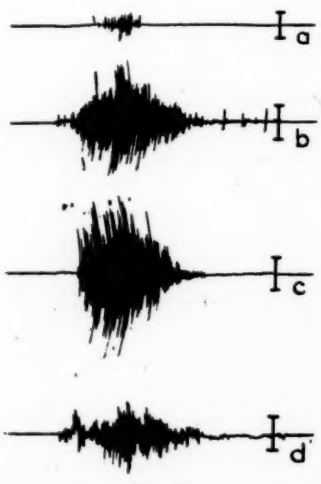


Fig. 3

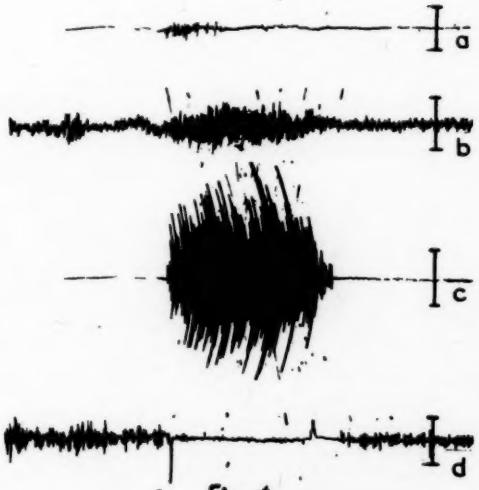


Fig. 4

Figs. 1 to 4. — E. M. G. during voluntary flexion of the wrist in pronation: (*a*) biceps; (*b*) triceps; (*c*) flexor carpi radialis; (*d*) extensor capri radialis. Vertical line equals 100 microvolts; horizontal line equals 1 second. Tension of flexion equals 9, 6, 6 and 8 pounds in figures 1, 2, 3 and 4, respectively. All records read from right to left.

potentials in the extensor carpi radialis, it seems to follow that activation of the triceps is associated with that of the flexor carpi radialis in pronation. This conclusion is confirmed by the experiment of figure 4, in which the triceps and extensor carpi radialis showed tonic activity. On flexion of the wrist, marked activity appeared in the flexor carpi radialis and the action potentials of the triceps were increased in a manner similar to that seen in atonic muscles. The extensor carpi radialis, however, shows actually an inhibition during flexion of the wrist. From these experiments it seems to follow that flexion of the wrist in pronation is associated with activity of the triceps, which may occur in the absence of action potentials of the extensor carpi radialis or even when the tone of this muscle is inhibited.

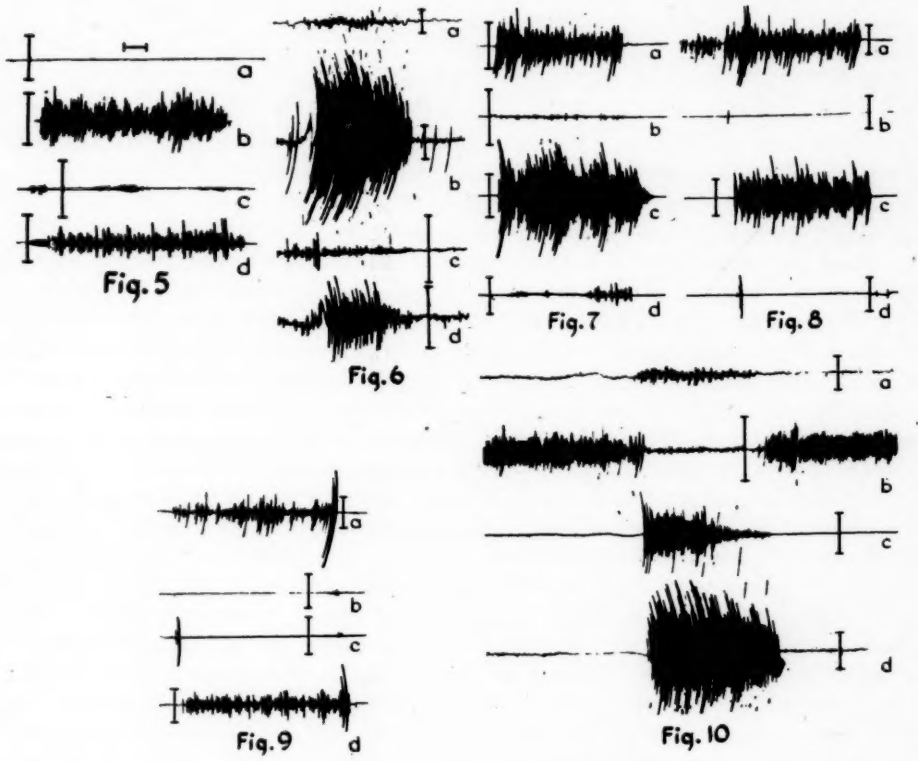
II. *Extension of Wrist with Hand Supinated.* — As in the experiments described in section I, uniform results were obtained in all 12 subjects, showing that extension of the wrist in supination is associated with activity of the triceps muscle (fig. 5). Again, individual differences exist with respect to the simultaneous appearance of action potentials in the antagonist (flexor carpi radialis), but, in general, the activity was slight or completely absent in this muscle. With excessive activation of the extensor carpi radialis very small action potentials may appear in the biceps at a time when the activity of the triceps is relatively strong. But here, again, the degree of activity is very marked in the agonist (extensor carpi radialis) and in the associated synergist[3] of the elbow (triceps) and very slight, if present at all, in the extensor carpi radialis and biceps. The quantitative relations in the electromyograms of figures 5 and 6 and in many other similar records obtained under these conditions show that the activity of the flexor carpi radialis is secondary to that of the extensor and that of the biceps secondary to that of the triceps.

III. *Flexion of Wrist with Hand Supinated.* — The activation of the upper arm muscles under conditions of flexion of the supine wrist uniformly follows the rule that, with sufficient stress, activity of the wrist flexors is associated with that of the biceps muscle. In the experiment reproduced in figure 7 action potentials appeared in the biceps when the flexor of the wrist exerted a tension of 12 pounds. But such associated activity was absent when the tension was 9 pounds (record omitted). In figure 7 one notices a slight coinnervation of the extensor carpi radialis. However, that this is not a prerequisite for the innervation of the biceps is clearly seen in the record, since the biceps activity is continuous throughout the activation of the agonist (wrist flexors) whereas that of the extensor carpi radialis is slight and discontinuous. Moreover, biceps activity may be associated with the flexion of the wrist in supination, as in the experiment of figure 8, although no action potentials appear in the extensors of the wrist. Occasionally it was seen that some activity persisted in the upper arm muscles after the period of contraction of the agonist had ceased. This phenomenon is illustrated for triceps and biceps muscles in figures 1 and 8, respectively.

IV. *Extension of Wrist with Hand Pronated.* — This was the only type of movement in which the innervation pattern did not show complete agreement among the experimental subjects. There was a tendency for several persons to activate the flexors as well as the extensors of the wrist in this movement, and frequently both biceps and triceps were activated to a similar degree. Nevertheless, it seems justified to utilize for a discussion of the physi-

3. That the upper arm muscles act synergistically with the agonist will be shown later. Since this action is not covered by Fulton's definition (Fulton, J. F.: Muscular Contraction, Baltimore, The William & Wilkins Company, 1926 — "Synergic muscles, i. e., muscles which act in the same direction mechanically at the same point, or which act similarly at two neighboring points") and is at variance with Duchenne's use of the term synergism (Duchenne de Boulogne, G. B. A.: Physiologie des mouvements démontrés a l'aide de l'expérimentation électrique et de l'observation clinique, et applicable a l'étude des paralysies et des déformations, Paris, J. B. Baillière et fils, 1867), it is referred to as associated synergism.

ology of the innervation pattern those experiments on wrist extension in pronation in which no co-innervation of the flexor carpi radialis occurs and in which only one of the muscles of the biceps-triceps group is activated. A typical example (fig. 9) shows that wrist extension in pronation is associated



Figs. 5 and 6. — Extension of the wrist in supination. Figs. 7 and 8. — Flexion of wrist in supination. Figs. 9 and 10. — Extension of wrist in pronation. Other symbols as in figs. 1 to 4.

primarily with contraction of the biceps muscle. Moreover, this pattern appeared regularly when, without fixation, an isometric extension of the wrist in pronation was performed by pressing the dorsum of the hand against a fixed board. That the biceps is the associated synergist follows also from experiments similar to those seen in figure 10, in which the triceps showed a marked tone. On extension of the wrist with hand pronated the tone was inhibited while action potentials appeared in the biceps.

Comment

The experiments show that under conditions involving flexion or extension of the wrist against springs of varying strength the degree of stress determines, within certain limits, the pattern of innervation. Under light stress the action potentials are confined to the agonists (i. e., flexor carpi in flexion and extensor carpi in extension), whereas under greater stress muscles of the upper arm are called into action. Since this action was observed many times without appearance of action potentials in the antagonist (i. e., in the wrist flexors during extension and vice versa; compare figures 1, 4, 5, 8 and 9) it may be said that activity of the upper arm muscles is not dependent on the fixation of the wrist.

In the table are summarized the results of our experiments, showing that pronation or supination determines whether the biceps or the triceps is activated with the agonist of the wrist muscles.

Effect of Various Movements of the Wrist on the Innervation of Biceps and Triceps

Movement	Agonist	Associated Muscle
Flexion in pronation	Flexor carpi	Triceps
Flexion in supination	Flexor carpi	Biceps
Extension in pronation	Extensor carpi	Biceps
Extension in supination	Extensor carpi	Triceps

A simple consideration of the mechanical conditions prevalent in the four groups of experiments shows clearly that the activated upper arm muscles intensify the action of the flexors and extensors of the wrist. Thus, flexion of the wrist with hand pronated is reinforced by the triceps muscle for the following reasons. When the hand is flexed against the spring of our apparatus in which wrist and forearm are well fixated, there is a tendency for the wrist to push against the upper part of the clamp. A force moving the wrist downward toward the spring would obviously aid in the performance of flexion in pronation, and such a movement would result from innervation of the triceps muscle, as was observed in our experiments. It was expected that the upper muscles would come into action when, through fixation of the wrist, hand and forearm had been changed into one mechanical unit. However, the observed results, showing a synergistic action of wrist and upper arm muscles without fixation of the wrist, represents a mechanism of similar efficiency and greater economy. Similarly, in supination it is the biceps which exerts its force in the same direction as does the flexor carpi radialis, and it is this combination of forces which is invariably evoked in the experiments described in section III. Similar considerations show that biceps and triceps are the synergists of the extensors of the wrist in pronation and supination, respectively. The reader may demonstrate to himself these relations by placing the hand in pronation or supination on or below a horizontal board and then palpating the upper arm muscles while he exerts pressure against the board in pronation and supination with the flexors or extensors of the wrist as agonists.

It was pointed out that the innervation pattern is modified by the degree of stress. With slight effort, action potentials appear in the agonists only (e. g., in the flexor carpi radialis and ulnaris on flexion of the wrist). As the effort increases in intensity, synergists in the upper arm (biceps or triceps) are called into action. With maximal force activity appears in flexors and extensors of wrist and elbow, but even here the characteristic pattern observed at the intermediate degree of activity is preserved. Thus, figures 3 and 6 reveal different patterns of activity, in spite of the presence of action potentials in all four recorded muscles. The pattern seen in figure 3 is clearly developed from that depicted in figure 1, and a similar relation holds for figures 6 and 5.

It was noted in an earlier study on the cat that with increasing intensity of cortical stimulation action potentials appear not only in the agonist but also in the antagonist.[1b] Similar relations are valid for the human subject under conditions of voluntary innervation.[4] In the light of these findings, the activity of the extensors of the wrist seen in experiments involving wrist flexion as well as the potentials found in the flexors of the wrist during its extension are clearly the expression of such a co-innervation. Our experiments show that co-innervation is not confined to that of the antagonist of

4. Bosma, J. F., and Gellhorn, E.: Unpublished observations. Hathaway, S. R.: J. Exper. Physiol. 18:285, 1935.

the primarily activated muscle (agonist) but appears, likewise, in the antagonist of the associated muscles of the upper arm which were recognized to be the synergists of the agonists. Thus, the pattern illustrated in figure 3 is interpreted as follows: Considerable action of the flexor carpi radialis (agonist) is accompanied by action potentials in its antagonist (extensor carpi radialis); likewise, activity in the associated muscles (triceps), if great enough, leads to co-innervation of its antagonist (biceps).

The adaptive character of this pattern is apparent. The co-innervation leads to a slight fixation of wrist and elbow and gives thereby increased stability to the arm. The movement of the latter is accounted for by the difference in the degree of activation between the principally functioning muscles (agonists and associated synergists) and their respective antagonists.

There is still another important difference between these two groups of muscles. Whereas the innervation patterns, as far as the combination agonist-synergist is concerned, are fully predictable and constant for each of the four sets of movements studied in this paper, the behavior of those muscles which are subject to co-innervation is variable. Some persons show more co-innervation than others. Moreover, it has been shown that these muscles when tonically innervated may show inhibition instead of co-innervation. As figure 4 indicates, co-innervation of the muscles of the upper arm may occur while the wrist muscles are in a state of reciprocal innervation, whereas in the experiments of figure 10 reciprocal innervation of the associated muscles is combined with co-innervation of the wrist muscles. Obviously, the behavior of the co-innervated muscles is of little or no importance for the development of the innervation pattern — i. e., the selection of the appropriate synergist which is called into action when a movement of the wrist is performed. Thus, figures 1 to 4 show that flexion of the wrist in pronation is associated with contraction of the triceps, independent of whether the extensor carpi radialis contracts (figs. 2 and 3), is inactive (fig. 1) or is inhibited (fig. 4). That the presence of tone in a muscle does not lead per se to inhibition is evident from experiments in which the associated innervation of the triceps occurs during flexion of the wrist in pronation in a tonically innervated muscle (fig. 4).

The conclusion drawn from these experiments as to the agonist-synergist relationship is confirmed by a more detailed discussion of figure 10. In this experiment (extension of wrist in pronation) the extensor carpi radialis induces a synergistic action in the biceps. The marked co-innervation of the flexor carpi radialis remains without effect on the upper arm muscles. This is remarkable, since the same muscle (flexor carpi radialis) in the same position (pronation) when activated in a similar degree but as an agonist (i. e., in wrist flexion) calls forth as synergist the triceps (cf. figures 1 and 2), whereas in the experiment of figures 10 the triceps is inhibited. From this discussion it follows that the activation of the biceps and triceps muscles is co-determined by the agonist only. Even a relatively powerful contraction of a muscle acting antagonistically to the executed movement fails to induce activity in the associated synergic upper arm muscles. This peculiar fact guarantees the maintenance of the characteristic innervation pattern—i. e., the typical agonist-synergist relationship in spite of marked contraction of the primary antagonist. Apparently it is the functional role of the muscle and not simply the degree of its activation which determines associated synergic contraction.

One might think that the different patterns of innervation associated with the activity of the agonist as contrasted with that of the co-innervated

antagonist, are linked up with differences in muscle length, since the agonist is shortened and the antagonist is lengthened. However, even under strictly isometric conditions (e. g., pressure of the palm or dorsum of the hand a fixed board) the same results prevail.

It is not improbable that the observations on synergitistic innervations are of practical importance. If a muscle or a group of muscles are paralyzed to a considerable extent, it may be difficult to exercise these muscles properly by means of voluntary movements. However, if another muscle group were intact which, under conditions of isometric or isotonic contraction could bring into action the partially paralyzed muscles as synergists an adequate flow of impulses could be provided which may prevent atrophy and contracture[5] until through nerve branching[6] or other processes the innervation of the muscle was improved. Pertinent observations made on patients with poliomyelitis will be reported elsewhere.

Summary

Electromyograms are recorded by means of surface electrodes from the flexor and extensor carpi radialis and biceps and triceps muscles during flexion and extension of the wrist with the hand pronated and supinated.

It is found that three stages, depending on the degree of stress, may be distinguished. In the first, the activity is confined to the agonist. In the second action potentials appear in the agonist and a muscle of the upper arm according to the following rule: Biceps activity is associated with flexion of the wrist in supination and its extension in pronation, whereas the triceps is activated when the wrist is flexed in pronation or extended in supination. The observations show that not the degree of activity of the wrist muscles but the type of movement performed determines which of the upper arm muscles is activated. The upper arm muscles thus selectively called into action are shown to be synergic with the agonists. In the third stage, under conditions of considerable stress, action potentials appear also in those muscles which are the antagonists of agonist and synergist, but their activation is so much less than that of the latter group that the characteristic innervation pattern is maintained.

The adaptive character of this innervation pattern and its significance for pathologic conditions are pointed out.

5. Tower, S. S.: J. Comp. Neurol. 67:241, 1947.
6. Van Harreveld, A.: Am. J. Physiol. 144:147, 1945. Weiss, P., and Edds, M. V., Jr.: ibid. 145:587, 1946.

The technical assistance of Mr. Henry M. Ballin is gratefully acknowledged.

RECONDITIONING FOR TUBERCULOUS PATIENTS *

With Special Reference to Those Requiring Thoracic Surgery

O. LEONARD HUDDLESTON, M.D., Ph.D. *

Associate Professor of Medicine, University of Southern California, School of Medicine and Director of the Department of Physical Medicine, Los Angeles County General Hospital.

LOS ANGELES

The major portion of the surgical treatment of pulmonary tuberculosis during the past twenty-five years has utilized some form of collapse therapy. However, during the past decade surgical removal of the diseased tissues has been added to the list of procedures.[1] Lobectomy, pneumonectomy and excision of tuberculomas are being employed with increased frequency in selected cases. Therefore, two surgical principles are now in current use: (1) that of collapse therapy, which brings about a reduction in pulmonary volume, and (2) excisional surgery, which utilizes excision of the diseased tissue. The various operations which employ these principles may be grouped under the heading of "curative therapy." There is still another phase of treatment which must be taken into consideration when certain kinds of thoracic operations are performed, namely, that of preventive therapy. This treatment includes preventive measures necessary to avoid the development of physical defects, postural deformities and functional deficiencies of the trunk and upper extremities. Some of the important problems to contend with before and after the surgical treatment of pulmonary tuberculosis are those of a debilitating disease, a lowered vital capacity and asymmetrical muscle power on the two sides of the body which may directly or indirectly give rise to postural defects or limited motion of joints of the trunk or shoulder.

The operative procedures which commonly give rise to conditions which require preventive therapy are those of thoracoplasty, lobectomy, pneumonectomy and thoracotomy for the removal of a tuberculoma or for the treatment of an empyema.

Fitzsimons General Hospital, in addition to being a center for the treatment of tuberculosis, is also a center for chest surgery. During the past four years a comprehensive preoperative and postoperative physical therapy and physical reconditioning program has been developed at this institution.[2] A portion of the program has been extended to the treatment of tuberculous patients requiring thoracic surgery. This additional treatment has been confined largely to certain phases of physical therapy. A brief description of the program as applied to chest surgery patients will suffice to illustrate

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* Former Chief, Physical Therapy Section, Fitzsimons General Hospital.

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the principles involved in the preoperative and postoperative care of the tuberculous patients. One or more physical therapists are assigned full time to the chest surgery wards. The physical therapists receiving such assignments have had special training in the therapeutic program utilized in the treatment of chest surgery patients. When a patient is transferred to the surgical ward, he is interviewed immediately by the physical therapist who learns as much as she can about the patient's physical condition, his diagnosis and the proposed type of treatment he is to receive. Frequently this information is known to her before the patient is transferred, because one of her duties is that of attending all the meetings of the Chest Surgery Reviewing Board. After this information has been obtained, the preoperative physical therapy treatment is instituted. This consists of orientation, in which the entire physical therapy program is explained, including the treatment and reasons for its employment, taking care to inform the patient exactly what to expect and what he is expected to do after his operation. Following this, additional instruction and practice in the use of the therapeutic exercises is provided prior to operation. A detailed outline of the exercise program is presented to the patient preoperatively, and an adequate number of practice repetitions are made for the exercises to be learned thoroughly. The immediate postoperative stage begins on the first postoperative day. This phase of treatment usually includes the proper alinement of the patient in bed, a small pillow being placed in the interscapular region of the back and an infant's pillow substituted for a large one. Some assistance is given the patient when a coughing program is to be carried out. Shoulder, abdominal, postural and sometimes breathing exercises are instituted during this phase of the treatment. The intermediate postoperative phase utilizes the progressive development of the exercises initiated while the patient is still confined to bed. These include posture training and posture exercises in addition to the more advanced breathing, shoulder and abdominal exercises.

For nontuberculous patients a late postoperative treatment program supplements that of the intermediate phase. Patients are sent to the physical therapy clinic where they receive advanced posture exercises, active resistive exercises and heavy resistance exercises. During the first three phases of the physical therapy program—namely, the preoperative, immediate postoperative and intermediate postoperative phases—the treatments are carried out in the ward. The late postoperative stage involves the use of special equipment provided by the physical therapy clinic. Tuberculous patients do not receive the late postoperative treatments and are not sent to the physical therapy clinic. Patients with tuberculosis who have undergone thoracotomy are treated in essentially the same manner as nontuberculous patients except that the exercises are less strenuous and the emphasis in the treatment is directed toward maintaining full range of motion of joints and of either correcting or maintaining good postural alinement. Emphasis is placed upon shoulder and posture exercises rather than upon breathing exercises, and in cases in which thoracoplasty is performed exercises are avoided which tend to retard or minimize the collapse of the thoracic wall.

Exercises

Following is a list of exercises commonly employed during the postoperative treatment of patients following an extensive thoracotomy. The exercises are used in progression consistent with the physical condition and exertion tolerance of the patient.

A. *Shoulder Exercises*

1. Passive range of motion of the shoulder in all directions within tolerance of the patient (for a short time the shoulder movements are carried out by the physical therapist).
2. Active assistive exercises carried through the range of motion, particularly abduction, flexion and horizontal adduction; internal and external rotation.
3. Active exercises through the range of motion in all directions.
4. Patient supine; physical therapist grasps wrist on affected side and exerts mild stretching to the lateral chest and abdominal muscles.
5. Shoulder ladder exercises; patient instructed to perform the exercises in flexion and in abduction with outward rotation.

B. *Abdominal Exercises*

1. Patient maintains supine position — good axial alinement, pillow under knees, static contraction of abdominal muscles.
2. Patient supine, knees semiflexed and supported by a pillow, then raises head forward, flexes neck and attempts to place chin on sternum.
3. Patient supine, knees extended, raises lower extremities by flexing the hips, increasing the degree of hip flexion as muscle power increases.
4. Patient supine, knees bent to 90 degrees, raises knees together toward the chest and then lowers them to starting position with knees still at 90 degrees; back is kept flat.
5. Patient raises head and shoulders to meet knees when knees are flexed 90 degrees.
6. Patient supine, arms above head, raises right arm and left leg to meet over body, lowers and repeats, using alternate arms and legs.
7. Patient supine, raises body to a sitting position with arms crossed on chest, keeping back rounded.

C. *Postural Instruction and Posture Exercises (posture training begins in the immediate postoperative stage and continues until the patient leaves the ward).*

1. Proper alinement in bed while patient is in a supine position; a small infant pillow is substituted for the large pillow, and a second small pillow placed in the interscapular region of the back. (These procedures are done to counteract the tendency to develop flexion of the head and drooping of the shoulders.)
2. Patient in sitting position before a mirror practices proper alinement of the head, neck, shoulders, and trunk.
3. Patient, in standing position before a full-length single or triple posture mirror, performs posture training exercises. (Practice in proper alinement of the feet, knees, pelvis, trunk, shoulders, head and neck is carried out after the patient becomes ambulatory in the ward).

D. *Exercises to Strengthen Scapular Muscles, Particularly the Rhomboid and Trapezius Muscles*

1. Patient in prone position, fingertips touching behind neck, arms in the position of abduction and outward rotation, lifts elbows from bed and places shoulder blades together.
2. Patient in prone position, arms extended behind back in position of outward rotation with hands grasped, raises arms above back and pinches shoulders together.
3. Patient in sitting position, holds towel or wand with hands about 15 inches apart; raises both arms in flexion and then lowers them, placing towel or wand behind neck; raises hands above head and lowers them to a position of extension.

E. *Breathing Exercises (when patient is in supine position, it is advisable to place a pillow under the knees to relieve tension on the lower back muscles)*

1. Costal breathing (ninth rib breathing); patient places hands at the level of the ninth rib with his fingers parallel to the ribs, fingertips pointing together, inhales deeply and forcefully, resisting the increase in chest expansion by pressure of the hands.
2. Diaphragmatic breathing; patient supine, arms in an inverted "T," knees bent. Inhales, raising chest as much as possible; keeps chest elevated and exhales; repeats once or twice and then lowers chest.
3. Patient supine, arms at side, flexes both arms, inhaling deeply until complete flexion is obtained; holds and releases air slowly as arms are lowered sidewise.
4. Same exercises as preceding except for addition of resistance with hands on

returning to the side; physical therapist grasps wrist of patient and offers resistance as arms are brought to sides.

5. Patient standing, flexes arms and rises on toes to maximum possible extension, holds and releases arms slowly to side (inhales during flexion and holds breath before release).
6. Same as 5 except that patient takes a few steps on toes while in position of maximum extension, still holding breath before release.
7. Patient in supine position, excursion of the normal hemithorax restricted by manual resistance offered by physical therapist, who places hand and forearm on the chest and adds sufficient body weight to limit the motion of the chest on the unoperated side; patient is encouraged to expand fully the hemithorax on the operated side.

It should be pointed out that in postoperative treatment of tuberculous patients the rate of progression of the exercises is considerably slower than that employed in the treatment of nontuberculous patients. Breathing exercises are not performed as frequently or as vigorously by postoperative tuberculous patients.

Sample case histories are presented to illustrate the application of physical therapy for tuberculous patients following thoracic surgery.

CASE 1. — *Thoracoplasty, left chest; diagnosis*: (1) *tuberculosis, pulmonary, bilateral, moderate;* (2) *empyema, tuberculous, extensive, left hemithorax.*

An ex-private, aged 25, was admitted to Fitzsimons General Hospital on Oct. 12, 1942. His history revealed that in December, 1941 he was found to have pulmonary tuberculosis by routine roentgen examination of the chest. His illness was discovered at the time of a physical examination for the flying service. Bilateral pneumothorax therapy was instituted soon after the diagnosis was established. In April, 1943 roentgen examination revealed a cavity in the left lung at the level of the second anterior interspace. On Sept. 4, 1943 an intrapleural pneumonolysis was performed. After this procedure the cavity in the lung decreased in size and finally disappeared. In February, 1944 bilateral hydropneumothorax developed which was more marked on the right than on the left. Repeated roentgen examinations showed a progressive increase in the amount of fluid present. In March, 1944, 900 cc. of fluid was aspirated from the right chest. Repeated aspirations were continued at regular intervals. The pleural fluid was turbid and greenish, and repeated cultures were positive for tubercle bacilli. Eventually multiple draining sinuses developed over the lower left side of the chest. The sinuses were associated with an empyema of the left side of the chest and collapse of the left lung. It was decided to do a complete thoracoplasty in order to collapse the empyema space. On May 7, 1944, the first stage thoracoplasty was performed with removal of portions of the first five ribs. On May 26, 1945, an anterior stage thoracoplasty was done with removal of the anterior segments of the second to the sixth rib, inclusive. The drainage from the sinus tract persisted. On Sept. 25, 1945, an abscess developed in the lower left portion of the chest which required repeated aspirations. On Feb. 7, 1946, a third stage thoracoplasty was performed, and segments of all the remaining ribs were removed. The patient's postoperative condition was good, even though the sinus tract continued to drain a considerable amount of purulent material from the left chest. Sputum studies in March, 1946 were negative for tubercle bacilli. Beginning with the first stage thoracoplasty, physical therapy consisting of passive, active and active resistive exercises for the muscles of the shoulder girdle were carried out in progression. Abdominal exercises and posture exercises combined with posture training were continued while the patient remained in the chest surgery ward. He was instructed to continue his exercise program after returning to the medical service.

CASE 2. — *Lobectomy, lower and middle lobes, right lung; diagnosis: tuberculosis, pulmonary, chronic, active, lower and middle lobes, right lung, with cavitation.*

A private, first class, aged 22, admitted to Fitzsimons General Hospital on Oct. 17, 1945. The history revealed that in 1944 this patient was associated with a friend who was known to have pulmonary tuberculosis. He remained in excellent health until September, 1945, when a moderate cough developed. This was followed by the development of expectoration of a small amount of mucopurulent sputum. He raised about 5 cc. of foul-smelling sputum daily. He also noted the development of night sweats and a slight amount of wheezing on deep breathing. He reported at sick call repeatedly and was given cough medicine to allay his cough. Chest films were taken in October, 1945, at which time a lesion in the right lower lobe was revealed. He was hospitalized on Oct. 16, 1945 and transferred to Fitzsimons General Hospital October 17. On admission, the patient appeared chronically ill. He had a moderate

cough, which was more pronounced in the morning. He was expectorating about a teaspoonful of foul-smelling, greenish-yellow sputum. There had been no significant loss in weight. Physical examination revealed essentially normal conditions except for pulmonary symptoms. There were limitation of excursion of the base of the right side of the chest and impaired resonance, and the whispered voice was decreased. Breath sounds were diminished in the right axilla and at the base posteriorly. He was examined by the Chest Surgical Reviewing Board on Jan. 5, 1946, at which time it was decided to treat the patient by lobectomy. He was transferred to the chest surgery ward, and preoperative penicillin therapy and the preoperative physical therapy routine were started. On January 18 he was operated on, the right lower and middle lobes being removed. The patient was returned to the ward in good condition. Roentgenograms of the chest taken on February 4 showed good reexpansion of the remaining portion of the right lung. There were a number of multilocular air pockets contained in the fluid present in the right space. The patient's general condition was good, and he remained afebrile. On February 23 he was transferred back to the medical service for further evaluation, treatment and final disposition. The physical therapy routine, including the immediate and intermediate postoperative phases, was started on the first day after operation. The exercise program included progressive breathing, shoulder, abdominal and posture exercises. When transferred back to the medical service, there was full range of motion of the shoulder, satisfactory bilateral expansion of the chest and an improvement in posture.

CASE 3. — *Pneumonectomy, left; diagnosis: tuberculosis, pulmonary, both lobes, left lung.*

A flight officer, aged 25, was admitted to Fitzsimons General Hospital on June 8, 1945. On Jan. 23, 1945, he was shot down over France. It was noted at the time of hospitalization that he had a high fever and atelectasis of the left lung. He also sustained multiple contusions and abrasion of the face, neck, and back at the time of the crash. Serial roentgenograms of the chest showed persistent atelectasis of the left lung accompanied with a shift of the mediastinum to the left. There was mottling of the left lung with areas of decreased density, suggestive of honeycombing. Physical examination revealed shifting of the trachea to the left, dullness over the entire left side of the chest, diminished breath sounds and numerous rales. Sputum examination revealed the presence of a large number of acid-fast bacilli. The patient was evacuated to the zone of the Interior and transferred to Fitzsimons General Hospital, where reexamination showed extensive consolidation of the left lung, associated with marked retraction of the trachea and mediastinum to the left and an elevation of the left diaphragm. Sputum examinations revealed the presence of acid-fast bacilli. A regimen of strict bed rest was instituted. Roentgenograms of the chest taken on June 19, 1945 indicated massive atelectasis of the left lung with only slight aeration of the left lower lobe. Bronchoscopy was then done, but no evidence of obstruction was found. During the bronchoscopic examination, however, a small amount of mucoid secretion was seen in the bronchial tree on the left side. The patient was kept on a strict bed rest routine. Within a period of four months he became afebrile. Results of laboratory tests, including the electrocardiogram, were essentially normal. On November 7 patient was seen by the Chest Surgical Reviewing Board, at which time more recent as well as the older roentgenograms were reviewed. Bronchiectatic honeycombing cavities were noted within the partially atelectatic left upper lobe. The right lung appeared normal. The Board recommended pneumonectomy, as it was felt that this was the only procedure that offered any chance of cure. He was transferred to the chest surgery ward, and penicillin therapy and preoperative instructions in physical therapy were started. Within a short time after the injections of penicillin were started, pronounced erythema of the skin and edema of the larynx developed. Penicillin therapy was promptly discontinued and sulfonamide therapy substituted. On November 27 a left pneumonectomy was performed. The postoperative course was essentially uneventful. The physical therapy routine for the immediate and intermediate postoperative phases was started the next day after operation. The frequency and the severity of the exercises were progressively increased during his stay in the surgical ward. Included were breathing, shoulder, abdominal and postural exercises. On Jan. 22, 1946, the patient appeared before the Chest Surgical Reviewing Board where he was examined and the roentgenograms of his chest reviewed. It was decided to return him to the medical service for further observation and disposition. After the operation the patient's sputum remained negative for tubercle bacilli.

A cursory examination of the statistical data regarding the surgical treatment of tuberculosis at the Fitzsimons General Hospital shows the following figures, which are of considerable interest: During the five year period extending from May, 1941 to May, 1946, there were 1,046 phrenic interruptions,

251 pneumonolyses, 531 thoracoplasties, 50 lobectomies, 7 pneumonectomies and 12 thoracotomies for excision of tuberculomas. No physical therapy was used in the treatment of the largest group of patients, those with phrenic interruptions. As a rule, no physical therapy was employed in the treatment of patients receiving pneumonolysis. However, in the last four groups — patients receiving thoracoplasties, lobectomies, pneumonectomies and excision of tuberculomas — routine physical therapy was employed more or less in accordance with the description of the treatment program outlined previously. The frequency and the severity of the exercises were individualized for each patient and kept safely within what was believed to be the tolerance of physical exertion. In other words, the routine followed in the postoperative treatment of tuberculous patients was essentially the same as that employed for other persons undergoing thoracic operations except that the exercises were milder.

In the postoperative treatment of thoracoplasty no breathing exercises are employed. Patients are requested to lie on a hard pillow placed beneath the side on which the ribs were removed, for ten minutes twice daily. However, even in such cases, shoulder motion and correct alinement of posture while lying in bed is started on the first postoperative day. The hard pillow routine is carried out daily for about one month after the last stage of the thoracoplasty is completed. Tuberculous patients in whom a decortication or a lobectomy has been performed are given the same exercise routine as nontuberculous patients, and they are gotten out of bed after the closed drainage tubes have been removed. At first the patient is required to stand by the bed for only a short time. When stability of balance is obtained and some strength has returned, the regular posture routine is started and breathing and shoulder exercises are continued with increased frequency and severity.

The physical therapy program constitutes a form of preventive therapy. The aims of the treatment are to prevent the loss of muscle power, and to avert development of stiff shoulders, poor posture and restricted movement of the chest wall. In case of thoracoplasty the aim of the treatment is to prevent the development of stiff shoulders and poor posture, especially a structural scoliosis, which, for the most part, may be prevented by proper instructions and faithful participation of the patient in the physical therapy program.

Preoperative Reconditioning

Interesting work in the treatment of tuberculosis in the medical service has been developed by Capt. George Erickson, Chief of the Reconditioning Service. A coordinated treatment program has been established, utilizing the services of the auxillary medical workers. A coordinated unit is built around the ward officer, who has the responsibility for the over-all care of each patient assigned to his ward. This is accomplished usually by a personal conference between the Chief of the Reconditioning Service and the ward officer, at which time an explanation of the plan of integrated therapy is made and the auxillary agencies placed at the disposal of the ward officer to aid him in the treatment of his patients. A therapy board or council is formed, with the ward officer serving as chairman. The other personnel of the board include the head ward nurse, the ward clerk or secretary, the ward program coordinator, who is a member of the Reconditioning Service, the ward educational counselor, who is a representative of the Division of Education and Recreation, the ward occupational therapist, the Red Cross recreation worker and the Red Cross social worker. A meeting of this group is called at which the ward officer explains to the group the plan for integrating the treatment of patients in his ward. Full cooperation is urged

of all the members of the therapy board. It is explained that the treatment should include medical care which involves the participation of all the group; it should include the medical and surgical treatment of tuberculosis as well as the psychologic, social, educational, economic, recreational and prevocational aspects of treatment. The representatives of the auxilliary agencies are reminded of their responsibilities in the treatment of each patient, and a cooperative treatment program is reviewed in which each supplies his individual contribution to the total care of the patient. Weekly meetings of this group are arranged, during which patients are discussed, suggestions are made by the various board members and, finally, definite plans for the over-all treatment of each patient are worked out and put into operation. A simple, comprehensive filing system has been established which is used by the various members of the board, so that at any time it is possible for one to ascertain from the cards exactly what has been done or remains to be done for each patient. The cards also provide space for pertinent comments which may be made by various members of the group. These filing cards serve as useful guides in the management and treatment of patients. Recently vocational and prevocational counseling has been included in the treatment program. A representative from the Veterans Administration and the United States Employment Service has been assigned to supply general advice to patients with tuberculosis regarding provocational and vocational activities. Vocational guidance, therefore, becomes an important part of the over-all treatment program. The prevocational activities of patients during their stay in the hospital are confined almost entirely to educational activities. Another important phase of the treatment of tuberculous patients has been included in the program — namely, that of orientation of the patient regarding his mental adjustment to the various aspects of tuberculosis. A series of orientation lectures have been developed and are presented by ward officers or by representatives of the Reconditioning Service to patients in the tuberculosis wards. These lectures include the following subjects:

1. An introduction, in which the aims and purposes of the orientation lectures are explained, and a brief history is given of the development of present knowledge of tuberculosis.
2. Causes, modes of transmission and methods of diagnosis of tuberculosis.
3. Anatomic and physiologic changes in the body caused by tuberculosis.
4. Treatment of tuberculosis, in which the emphasis is placed upon physiologic and psychologic rest.
5. Surgical treatment of tuberculosis, including various types of collapse therapy and major thoracic procedures, such as lobectomy and pneumonectomy.
6. A summary, which is conducted more or less as an oral review.

Additional lectures on vocational guidance and the social and economic aspects of tuberculosis are to be included in the orientation lectures.

It is interesting to note the similarity of this method of approach to the over-all treatment of tuberculosis with that recently developed by the Veterans Administration for use in general medical, general surgical and tuberculosis hospitals. These veterans' hospitals are requested to establish a rehabilitation board which is charged with the responsibility of providing total treatment of patients treated in these hospitals. The physiatrist serves as chairman of the board. Other representatives on this board are as follows: the ward surgeon, psychiatrist, physical therapist, occupational therapist, medical social worker and such other personnel as deemed necessary by the chairman of the board. These may include the clinical director, vocational guidance representative, chief of the retraining division and the librarian. The aims are (1) to establish rehabilitation as early as possible and (2) to provide a coordinated, cooperative treatment program, which includes the psychologic, physical, sociologic, economic, prevocational, educational and vocational aspects for each individual patient.

The main purpose for discussing this phase of the treatment of tuberculosis is to point out the trend which is developing both in military hospitals and in veterans' hospitals for the total treatment of individual patients and to point out the increasing prominence and responsibility of the physiatrist in this treatment program. It is probable that both in the Army and in the Veterans Administration the physician in charge of physical medicine will have the responsibility of integrating these various therapeutic activities as well as supervising and directing detailed therapeutic exercise programs employed in thoracic surgery for the physical rehabilitation of patients.

Summary

It has been pointed out that, by the use of a carefully planned physical therapy program consisting chiefly of therapeutic exercises, physical abnormalities such as faulty posture (scoliosis, drooped shoulder), limited joint motion and restricted movement of the chest may be averted. It is further stated that similar integrated treatment programs are being worked out in veterans' hospitals and in at least one Army Hospital which emphasizes the total treatment as complete medical rehabilitation of each patient. It is believed that the orientation program and the integrated therapy regimen as developed by the Reconditioning Service at the Fitzsimmons General Hospital and the Medical Rehabilitation program of the Veterans Administration Hospital will aid materially, not only in the medical treatment of pulmonary tuberculosis but in the surgical treatment as well.

A COMMUNITY REHABILITATION SERVICE AND CENTER *

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Since the early days it has been the practice of philosophers, academicians and scientists to gather together after wars or any other great periods of national emergency to discuss the philosophic and technical advances made during such emergencies in terms of their application to peacetime living. It has been said that man utilizes but 10 per cent of his potentialities in everyday living and calls upon his remaining reservoirs of strength and ability only in times of peril. The same observation might well be made of society as a whole, for in wartime, under the stress of danger and urgent necessity, we make spectacular advances. Wars certainly cannot be justified on the basis that their by-products bring certain benefits to mankind. Paradoxical as it seems, however, it is true that out of the suffering and chaos of war arise benefits for untold millions. In no field of endeavor is this anomaly better illustrated than in medicine and, particularly in this last war, in physical medicine and rehabilitation.

The present peak of interest in the problems of medical rehabilitation

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on the part of both the medical profession and the general public is a direct outgrowth of war. During the war the military services demonstrated what could be accomplished by planned, progressive programs of medical rehabilitation. Many doctors saw for the first time what could be done for a disabled patient. Physical medicine came of age. Our philosophic concepts kept pace with our technologic advances. Rehabilitation was taken from the realm of extensive theoretical discussion, in which its practical application was limited, and became the bridge from the acute hospital ward back to productivity.

Concomitantly, the interest of the medical profession and the general public in the problems of the disabled was heightened by the records of our handicapped and disabled during the wartime manpower shortage. Here many of the disabled found jobs for the first time. Industry welcomed them as the only known untapped source of manpower.

Over eight out of every ten industries in the nation employed impaired workers. Once on the job in large numbers, the handicapped proved conclusively that when selectively placed in jobs commensurate with their physical abilities they were equally as efficient as nonhandicapped workers and usually much more reliable and dependable.[1]

The handicapped proved their worth during the war and were lauded by industry for their efforts. But what happens now? As production was cut back immediately after V-J Day, industry had to drop large numbers from its payrolls. Demobilized veterans started to return from the war in increasingly large numbers, and more employees had to be released to make room for the veterans who not only deserved jobs but had them guaranteed by law. Dismissals were made on the basis of seniority, and the disabled, being the last to be hired, in most cases were the first to be dismissed.

The handicapped worker, after enjoying a period of economic prosperity, suddenly finds in the loosening labor market that jobs for which he can qualify are no longer available. Greater production during the war allowed industry to break job structures into small components, but now the average worker, instead of doing just one small highly specialized task, finds he must be able to do several. This demand for greater flexibility on the part of the worker further reduces the employment opportunities for the disabled. During the war the job was broken down and adapted to the worker. This can no longer be done. The answer lies only in building the worker through rehabilitation up to the level demanded by industry.

The solution to the dilemma of the handicapped worker is obvious, but it is far from simple. The Office of Vocational Rehabilitation of the Federal Security Agency has estimated that there are approximately one and one-half to two million persons in the United States who are seriously in need of extensive vocational rehabilitation. Prior to the onset of World War II the United States Public Health Service estimated there were some 23,000,000 persons in the United States who were handicapped by disease, accidents, maladjustment or former wars. Accidents alone increase this figure by 350,000 each year. During the period between Pearl Harbor and V-J Day 260,000 servicemen were permanently disabled as a result of combat wounds, but 1,250,000 civilians suffered permanent disabilities from accidents during the same four years.[2]

We have seen, read and heard of the rehabilitation opportunities afforded men disabled in military service. Yesterday we heard a comprehensive report by Dr. Covalt of the splendid strides made in the medical rehabilitation

1. Bridges, Clark: Job Placement of the Physically Handicapped, New York, McGraw-Hill Book Company, Inc., 1946, pp. 1-8.
2. Donahue, Wilma T., and Tibbitts, Clark: The Task Before the Veteran and Society, Ann. Am. Acad. Political & Social Sc. 239:1-9 (May) 1945.

program of the Veterans Administration. The man who was disabled in service is receiving every possible opportunity and advantage, but what has happened to the 43 out of every hundred men who were unable to pass Selective Service medical tests? What is being done for the 350,000 persons who are disabled each year from accidents? What is being done for the two million persons in this country whose correctible physical disabilities prevent them from holding jobs? Where can the casualties of the home front go to receive the aid they need?

That rehabilitation pays off economically has been demonstrated by the state vocational rehabilitation programs operating under the supervision of the federal Office of Vocational Rehabilitation. During the first full year of this agency's operation under the Barden-LaFollette Act which greatly expanded its services, aid was given to 161,047 handicapped men and women.[3] Of this number, 41,925 were rehabilitated to the mutual satisfaction of the clients and their employers to a sufficient point to obtain jobs. The remainder were still in the process of rehabilitation, or their cases were such that interview, counsel and guidance were sufficient to meet the client's needs.

Of the patients rehabilitated, nearly 79 per cent were unemployed at the time of undergoing rehabilitation and over 18 per cent had never worked previously. Over two-fifths had one or more dependents. Half were dependent upon their families, public or private relief or workmen's compensation. Their average monthly income, including public or private assistance, was $24. After rehabilitation, their average monthly wage increased to $147. The average cost of rehabilitation was but $300 per case, an investment which took them from the public or private assistance rolls and made them self-supporting wage earners.

The record of the federal-state rehabilitation programs with these 41,925 cases is encouraging, but it is woefully inadequate when compared to the one and one-half to two million who are urgently in need of such care and training.

The obvious question is, "If the rehabilitation program has been so successful with this small group, why aren't the remaining million and a half or two million given its advantages?" The immediate answer to that question is that there simply are not enough rehabilitation centers in the country to which these persons can be referred. The state and federal rehabilitation programs do not do the actual physical restoration and vocational retraining, but supply the funds, help select vocational objectives for which the persons possess both aptitude and physical abilities and supervise treatment and retraining. The actual work, however, is done by other agencies, either private or public. These agencies are schools, trade schools, apprenticeship training courses, rehabilitation centers, hospitals and other medical facilities.[4] Those agencies, however, which possess the necessary skilled personnel, equipment and facilities to do an adequate job of physical restoration and retraining to rehabilitate patients vocationally are so few in number that opportunity is denied to all but a few of our handicapped citizens.

Early in 1945 it was recognized by the Baruch Committee on Physical Medicine that much had been learned in the rehabilitation programs of the armed services which would be of value in the care of physically and emotionally disabled civilians and might help in breaking the bottleneck created by lack of facilities. A subcommittee on civilian rehabilitation centers, whose final report has just been published, was appointed to work out a simple

3. Annual Report of the Federal Security Agency: Section III, Office of Vocational Rehabilitation, 1945, Washington, D. C., Government Printing Office, 1946.
4. Shortley, Michael J.: Rehabilitation of the Civilian Disabled, Ann. Am. Acad. Political & Social Sc. 239:101 (May) 1945.

basic blueprint that would translate war rehabilitation experience into its civilian applications.[5]

The report outlines the mission, organization, physical setup and approximate cost of a community rehabilitation center and its importance to the community as a whole. Such a center would perform the invaluable service of centralizing and integrating all the rehabilitation resources of the community and those of industry and labor and the existing social and governmental agencies.

Rehabilitation centers are designed to take care of the third phase of medical treatment — which takes the patient from the bed back to the job. As envisioned by the plan offered by the Baruch Committee, they are to be constructed and operated on the principle of treating the "whole man." They are not places for domiciliary care, old folks' homes or institutions for incurables. They are training centers where those in need of rehabilitative care can go for physical rehabilitation, psychosocial treatment and adjustment, vocational guidance testing and retraining.

For example, the paraplegic patient can be taught to walk with the aid of braces and crutches. When this is accomplished, he can, through counseling and aptitude tests, discover the kind of work for which his talents and physical abilities would qualify him and start retraining himself for this work. When the period of training is completed, his ability can be evaluated by a selective placement specialist who will help him to find a job. The excellent results that can be achieved for the paraplegic are well exemplified by the rehabilitation program for paraplegics in the Veterans Administration.

It is emphasized in the report of the Baruch Committee that "rehabilitation service and rehabilitation centers are community projects, and all of the existing facilities and organizations in the community must be fully utilized. The rehabilitation center must be a part of the community rather than a thing within it. It is necessary to know what the community has to offer in terms of personnel and physical equipment. It must be a program of integration, and duplication should be avoided."

The initial costs of establishing a rehabilitation center would vary greatly in different sections of the country. It is estimated by the Baruch Committee, however, that the type of construction necessary would cost approximately 40 to 50 per cent less than that necessary in the average general hospital.

The committee estimates that the average patient will require a two month period for rehabilitation and retraining and that the administrative, educational and professional service will cost approximately $2.50 per patient-day. This does not include dormitory and food service. Seventy-five per cent of the patients in a rehabilitation center will be outpatients, and even for those requiring dormitory facilities the total cost of the rehabilitative care will be substantially less than the average day cost in the average hospital and will provide a dynamic retraining program.

It is expected that patients will be referred to the center by industry, insurance companies, labor, the Veterans Administration, State rehabilitation agencies, welfare groups, hospitals and physicians. Because of existing legislation and insurance coverage, the majority of the patients, or the agencies responsible for their care, will pay either full or partial fees for the service. With good business administration and the backing of the medical profession, governmental and welfare agencies and insurance companies, a center, once established, should be largely self supporting.

5. A Community Service and Center (Functional Plan), New York, The Baruch Committee on Physical Medicine, 1946.

There are but few rehabilitation centers operating at the present time within the philosophy and scope of those proposed by the Baruch Committee. Outstanding among these are the Institute for the Crippled and Disabled in New York, the Cleveland Rehabilitation Center, the Milwaukee Curative Workshop, the Montefiore Tuberculosis Sanatorium and the Warm Springs Foundation. The majority of such agencies, however, devote their specialized services to one particular group of the handicapped.

As an outgrowth of the war, however, a number of centers offering widely diversified programs are in the organizational stages. In San Francisco a community rehabilitation center is being built under the sponsorship of the American Women's Voluntary Services.

With varying sponsorship, plans are underway for centers in Chicago, Detroit, Houston, Kansas City and several other cities. In Bridgeport, Conn., where an excellent rehabilitation program is already functioning, leadership was first taken by the Connecticut Society for Crippled Children and Adults in cooperation with the State Division of Rehabilitation and the State Vocational Educational Bureau. Later the local Junior Chamber of Commerce also became a sponsor, and the center has developed into a vital community project. At Detroit the service is being organized and sponsored in association with Wayne University as an industrial rehabilitation project.

In Kansas City and in Durham, N. C., rehabilitation centers are being discussed as living war memorials. Community leaders feel that there could be no more fiting memorial than an institution capable of making a continuing contribution to the handicapped.

There are in the United States some six and one-half million working-age males who are either totally incapable of work or are employed only on a part-time basis because of handicaps. The majority of these men can become employable only by relearning some of the skills which have been lost through disabilities. Given such opportunity, they can, with good selective placement, become self sufficient.

The advances made in physical medicine and rehabilitation during the last five years are not limited to the new modalities and technics of treatment. We have learned that a great new field lies before us in which the utilization of physical medicine can increasingly broaden the social and economic horizon of the disabled person by teaching him to develop the great potentialities within himself. Our duty, as physicians, is not terminated with the diagnosis and treatment of disease. It ends only when our patients are returned to productive living.

Discussion

Dr. F. H. Krusen (Rochester, Minn.): There are three summarized statements I should like to make. First, physical rehabilitation or rehabilitation begins when a man is first injured or becomes ill and ends only when he is completely restored to maximal activity.

Secondly, I should like to bring out the point that has been made before, that physical rehabilitation is the much neglected third phase of medicine.

Third and last, I should like to point out that it has been said, and rightly, that rehabilitation fills the gap between the customary end point of medical care and the real necessities of most patients. We must devote strenuous efforts to enlarging the contributions of physical medicine to the third phase of medical practice. The end point of medical care should be extended and we should continue with this important work. You all realize that we are making real progress but there is much yet to be done.

THERAPEUTIC EXERCISES IN MANAGEMENT OF WAR INJURIES *

A Review

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The current upsurge of interest in therapeutic exercises was stimulated by the necessity for effective measures to restore severely injured war casualties. The problem of rehabilitation was so large in this war because of the great numbers of fighting men involved, the mechanization of warfare and the relatively lower ratio of battle deaths to injuries. Many persons severely injured on the battlefield survived because of the improvements in military medical care, particularly in the advance echelons. The many severely wounded casualties were a challenge to the practitioners of physical medicine —a challenge that for the most part was met successfully.

One factor in the successful management of war casualties that rapidly assumed importance was therapeutic exercises, and many of the lessons learned in its extensive application can be applied in civilian life. Hence it is felt that reemphasis of the principles of therapeutic exercises and a review of the major contributions to this field made during World War II will be of value.

Therapeutic and Reconditioning Exercises

Some confusion has been created by the development of reconditioning exercises in the armed forces and the current program for corrective physical rehabilitation in Veterans Administration Hospitals. Therapeutic exercises must be distinguished from reconditioning exercises or exercises for corrective physical rehabilitation.

During the war a reconditioning program designed to speed hospitalized casualties on the road to recovery was formulated by the Army Medical Department. The activities of the Reconditioning Service included physical medicine, occupational therapy, physical reconditioning and educational and recreation programs. The program for physical reconditioning consisted of exercises for the uninjured portions of the body. The exercises were begun while the patients were still bedfast and were continued until the patients were ready to return to military service or civilian life. Because of the success of the reconditioning exercises in Army institutions, where the Veterans Administration adopted a similar program for its hospitals these exercises are now being administered by personnel trained in physical medicine and in the Army program.

There was a tendency in some Army institutions — and it has developed in Veterans Administration Hospitals — for the reconditioning or rehabilitation personnel to administer therapeutic exercises. If this tendency continues, it is believed that it will interfere with the achievement of the best results from these exercises.

* Read at the Twenty-Fourth Annual Session of the American Congress of Physical Medicine, New York, Sept. 4, 1946.

The most effective administration of therapeutic exercises requires considerable training, skill and judgment, and results obtained by fully qualified persons are strikingly superior to those obtained by less expert personnel. Except in certain instances — as, for example, in cases of immobilized fractured backs, quadriceps setting or amputations—therapeutic exercises cannot be given routinely to groups; they must be prescribed to meet specific needs. Personnel administering such exercises require sound and thorough training in anatomy, kinesiology and physiology, as well as considerable knowledge of the conditions for which the exercises are given. Professional skills and judgments are required, and personnel should have a knowledge of and interest in management of sick or injured patients. Incidentally, far more extensive courses in muscle physiology should be given in the schools for physical therapy technicians. The present courses do not allow sufficient time for thorough teaching of this subject, but a sound knowledge of muscle physiology is indispensable for the proper administration of therapeutic exercises.

Reconditioning or rehabilitation exercises are given to the uninjured parts of the body to maintain general muscle tone and endurance, improve circulation and develop general well-being of hospitalized patients. To a patient with fracture of the right femur the physical therapy personnel administer therapeutic exercises to the glutei, the right quadriceps muscle, right knee, leg, ankle, foot and toes. To the same patient reconditioning personnel administer exercises to the muscles of the neck, upper extremities, torso and left lower extremity. Occasionally, as in the management of traumatic myelitis of the spinal cord or of amputations, demarcation of personnel function may become blurred; yet if functions and objectives of the two types of exercises are kept in mind there should be no conflict of professional interests or efforts. Physical therapy, physical reconditioning and occupational therapy personnel in the Army often were closely integrated, and their combined efforts helped to restore the patient as quickly as possible to maximum usefulness.

General Principles

The following principles, although elementary, proved so important during the management of war casualties that they are repeated here.

1. The patient's active and intelligent cooperation was essential. Time spent by physicians and physical therapy personnel in teaching patients the significance of their exercises and the way to perform them properly was rewarded by increased patient interest and better results. The patients' close attention and concentration during performance of the exercises were essential. Increase in strength and coordination as well as in circulation required that the muscles contract actively; indifferent performance of the exercises was a waste of time.

War casualties often had emotional disturbances, some of which were similar to the traumatic neuroses found in civilian patients. When the physician and physical therapy staff were cognizant of the patients' emotional problems and handled them properly, the response was gratifying and the patients' active interest in their exercises was high. This was an especially important consideration in case of patients with spinal cord injuries and of amputees.

2. Therapeutic exercises required careful prescription. Physical therapy personnel who administered the exercises had to know the specific medical problems of each patient and the types of exercises needed to correct the difficulties. It was the responsibility of the physician in charge of physical medicine to make clear in his prescription the specific diagnosis, including

the names of the involved structures, to outline the problems and to prescribe the types of exercises to be used. He also had to note the limitations and precautions to be observed and the reasons for them.

3. Prescriptions for therapeutic exercises had to meet specific physiological and anatomical needs. After tendon transplants, transplanted muscles required training in new functions. The quadriceps muscles of fractured femurs and injured knees required development of power. Patients with muscle disturbances due to brain injuries required long, long periods of specialized exercises designed to overcome the motor deficiencies encountered; each presented a different physiological problem and required a different type of exercise.

4. Therapeutic exercises had to begin early in the course of management. When exercises were started early and continued throughout the period of the patient's confinement to bed and throughout his convalescence, the end results were best. Development of a program for bedridden patients required that the director of physical medicine work at all times in close association with the other services. Rounds and active participation in staff conferences proved effective measures for educating his professional colleagues in the value of therapeutic exercises. When such activities were consistently part of the director's routine, the other services automatically referred their patients early. Early institution of therapeutic exercises saved months of prolonged attention later and sometimes prevented irremediable deformities.

5. Periodic checks of progress were made. Examinations, roentgen investigations and goniometer measurements were made at frequent intervals. When the patient's needs changed, the exercises had to be varied to meet the new conditions. In case of transplants, after coordination was achieved, speed and power were sought. In case of knee injuries, muscle power was the first objective, and heavy resistance exercises were given as early as possible.

6. Close coordination with physical reconditioning and occupational therapy helped speed restoration of maximal function.

Clinical Application

Most of the casualties belonged to the orthopedic surgery, neurosurgery and thoracic surgery services. Fracture of the extremities was among the commonest injuries. About 10 to 15 per cent of the injuries of extremities were complicated by nerve wounds. Mine and shell fragments and bullets caused serious and destructive wounds that necessitated prolonged immobilization. Serious threats to restoration of function were inherent in combined soft tissue, blood vessel, nerve and bone injuries. Many wounds were further complicated by infections. The more protracted the immobilization, the more important became therapeutic exercises.

Centers for orthopedic surgery, neurosurgery and thoracic surgery, with well equipped gymnasia, were established and staffed with qualified physical therapy personnel. Out of the extensive experience with therapeutic exercises during the war, several major contributions evolved.

Heavy Resistance Exercises. — Probably one of the most significant contributions to therapeutic exercises during the war was Captain De Lorme's work at Gardiner General Hospital, Chicago.[1] He became interested in the problem of reestablishing power in quadriceps muscles atrophied by disuse because of injuries to the knee and to the femur and turned to heavy weight-lifting because of a personal experience with this sport.

1. De Lorme, T. L., Jr.: Restoration of Muscle Power by Heavy Resistive Exercises, J. Bone & Joint. Surg. 27:645 (Oct.) 1945.

The heavy weight lifting exercises were based on the established physiological principles that muscle power is directly related to muscle size and that a muscle hypertrophies when it works at repeated intervals against an overload. De Lorme submitted atrophied quadriceps muscles in patients with unstable knees to periodic extension exercises with standard weight-lifting devices carrying the maximum poundage which the muscles could lift once to full extension once a week. On other days of the week the poundage was graduated, starting with low weights, and ten to fifteen repetitions were done with each weight. The total repetitions for each workout were limited to between seventy and one hundred. Complete flexion and extension were performed slowly, the weights being lowered and raised at the same speed and the motion never jerky. Momentary relaxation after each repetition was considered important. Details of the technic have been described elsewhere by De Lorme.[1]

The results for patients with postoperatively unstable knees were sometimes dramatic; consequently the exercises were adopted at other Army institutions. They were used for knees unstable from torn cruciate and collateral ligaments, after removal of menisci and after total synovectomy of the knee. They were also used in cases of fracture of the femur, patella and tibia in which muscular weakness and atrophy existed from disuse. The exercises not only stabilized the knees by building power of the quadriceps but also developed sufficient power in the musculature to shear adhesions that limited mobility of the knee. They succeeded in cases in which the older weight-bearing and stair-climbing exercises and exercises with pulley weights had failed. In some instances, there was complete clearing of the pain and swelling from chronic synovitis. De Lorme pointed out that pulley weight lifting exerts its greatest resistance when the quadriceps muscles are stretched and the knee is in 90 degree flexion; heavy weight lifting produces the greatest resistance against the muscle when the knee is fully extended.

Since De Lorme's original work he and Huddleston and others have extended the application of these exercises to other conditions. De Lorme designed a system of devices which included one to overcome flexion deformities of the knee and others to increase power of the muscles of the hips, ankles, back, shoulders, elbows and wrists. Huddleston successfully applied the exercises to patients with thoracic injuries.

Thoracic Surgery. — The Army Medical Department treated 54,000 patients with thoracic injuries during and just after the war. Centers for thoracic surgery were established here and abroad. In this country the centers were at Baxter, Brooks, Fitzsimons, Kennedy and Walter Reed general hospitals. Therapeutic exercises made notable contributions to the management of patients at these institutions requiring operations on the chest. One of the finest programs of exercises for such patients was developed by Lieut. Col. Ora L. Huddleston at Fitzsimmons General Hospital, in Denver. Lieut. Col. Wright E. Harken, Chief of Thoracic Surgery, 160th General Hospital, stated in a mimeographed note to the personnel of the thoracic services under this consultative guidance: "It is fair to say that one of the most valuable contributions to thoracic surgery in recent years has been the understanding and use of remedial breathing exercises. The 'fused chest' following thoracic disease, producing the 'pulmonary cripple," has become an unusual tragedy rather than the hallmark of thoracic surgery." He was enthusiastic about the results obtained with these exercises, and the exercises were required for patients under his care. He adopted the system developed by the English thoracic surgeon, A. Edward Tudors. For some time English

and Australian thoracic surgeons have utilized what are termed "remedial breathing," or "controlled breathing," exercises.[2]

At the time of injury the chest wall is painful and splinted. The affected portion of the wall stops functioning. In a short time the automatic neuromuscular mechanism is disrupted, and frequently it is not restored. Pleural adhesions maintain the immobilization, and a classic deformity develops. The head becomes tilted; the shoulder slides downward, inward and medially, and the shoulder — especially after an operation — may have limitation of motion. The chest wall becomes fixed in full expiration. There is scoliosis of the thoracic vertebrae with the concavity toward the injured side, and kyphosis and pelvic tilt develop. The vital capacity, as well as resistance to serious pulmonary infections, is lowered. The "pulmonary cripple" is in constant danger of economic dependence.

Therapeutic exercises to prevent and correct these deformities became a routine in the management of Army patients requiring thoracic operations. Huddleston introduced a number of innovations and brought these exercises to a new high level.

Three types of patients were treated at Fitzsimons General Hospital: (1) patients with chest wounds and intrathoracic injuries from shell fragments and bullets or compression from blasts or external violence; (2) patients with chronic infections, like tuberculosis, pulmonary abscess, empyema, fungus infections and bronchiectasis; (3) patients with tumors, such as granulomas, cysts and neoplasms. The surgical procedures ranged from thoracotomy, with and without rib resection and lobectomy, to plastic repair of chest walls and decortication of empyemas. Splendid organization, administration and physical therapy personnel all contributed to the effectiveness of the program. Immediately after the patient's arrival, he was examined for mobility of the shoulder, respiratory abnormalities and postural deformities. His problems were analyzed, and exercises to meet his needs were taught before the operation was done. If his condition permitted, he began the exercises preoperatively. On the first postoperative day he was started on the routine. His postural alinement — legs, hips, back, shoulders and head — was corrected while he was in the supine position. Coughing exercises, to expel secretions, were started within twelve hours after the operation. A small sandbag was placed between the shoulders to minimize retraction of the shoulders, a common postoperative deformity. Hot packs or dry heat to the shoulders or chest helped to relieve pain and prepare for the exercises.

Breathing and shoulder exercises also were started on the first postoperative day. The former were designed to enhance respiratory control, with symmetrical costal breathing. Attention was directed to the portion of the chest where breathing was shallow, and the patient was encouraged to use the part of the chest that lagged. As an aid, the physical therapist or the patient placed a hand at specified areas of the chest wall to help the patient to concentrate on breathing. Manual resistance or sandbags to the normal side of the chest limited its excursions and fostered movements of the involved side. During the first day breathing exercises were done five times an hour; they were then increased by five times an hour each day until the patient was doing them twenty-five times an hour, and this schedule was then maintained. Breathing exercises were continued when the patient became ambulant. Shoulder exercises were started at the same time as breathing exercises. If necessary, passive movement to the limit of pain tolerance was used. When some voluntary motion was possible, assistance in active movements was given. Flexion, abduction and outward rotation of the shoulder were encouraged.

2. Hayward, J. I.: Physiotherapy (Controlled Breathing) in Chest Surgery, Australian & New Zealand J. Surg 13:247 (April) 1944.

Exercises of the upper and lower abdominal muscles were started toward the end of the first postoperative week. Static contractions, raising the head, raising the head and shoulders, raising the flexed knees and raising the extended knees were the exercises taught. When the patient became ambulant, breathing, shoulder and abdominal exercises were combined and their intensity increased progressively to the limit of tolerance. For the first few days the patient received the ambulant treatment in the ward. To this program, other exercises, including intensive postural, active resistance and heavy resistance exercises for muscles of the shoulders, chest and abdomen, were added in the clinic. Usually three or four weeks after operation the patients were able to stop physical therapy procedures.

Therapeutic exercises for patients with thoracic conditions were combined with reconditioning activities.[3]

Fractures of Extremities. — Fractures of upper and lower extremities were common. Static contractions of immobilized muscles and active motion of joints proximal and distal to the immobilized part were administered early to maintain motility of free joints and to prevent adhesions and contractures. These procedures also prevented disuse atrophy and weakness and maintained tone and circulation. After removal of the immobilization device, the exercises became progressive, and movement of the joints above and below the fracture was started as soon as healing permitted. Passive exercises were rarely used. Painful motion due to strain on the callus was avoided, lest refracture, delayed union or angulation deformity result. The exercises after immobilization were administered with the aim of restoring motility of the joint, normal strength, tone, endurance and speed of muscle contractions and skill of movements and of overcoming existing defects. Shortening of muscles, contracture of ligaments and capsules and joint adhesions had to be combated by subsequent measures when early movement could not be administered.

In general, the whirlpool bath proved a satisfactory method of preparing fractured extremities for exercising and was used extensively for this purpose. Heat and massage and hot packs also were utilized.

In case of fractures of the humerus, static exercise of the deltoid muscle was started while the airplane splint or spica was still on. The deltoid atrophied rapidly when not exercised. When hanging casts were used, pendulum swinging was taught to keep the shoulder joint mobile. Adhesions, contractions and fibrosis of the shoulder cuff were sometimes troublesome after the casts had been removed. Mobility of the fingers, especially the thumb, was maintained by self-administered finger flexion, extension and opposition exercises. Progressive exercises, using first manual resistance, then friction and, finally, heavy resistance when healing allowed were effective in restoring function.

The axillary folds frequently became tight and restricted motion of the shoulder. Heat, massage, hot packs, self-administered passive pulley exercises and shoulder wheel, shoulder ladder, stall bar and heavy resistance exercises were used to increase shoulder mobility. Occupational therapy was prescribed to increase coordination, speed and skill, especially of the elbow, wrist and finger movements.

Fractures of the femur, often compound, required many months of immobilization. Early constant day-to-day attention to maintenance of tone and strength of the quadriceps and gluteus muscles, as well as to mobility of the patella, knee, ankle and toes, was important for the ultimate restoration of normal stance and walking. Exercises were begun as soon as the shock wore off.

3. Grow, J. B.; Raines, O. M., and Huddleston, O. L.: Reconditioning in Chest Surgery, J. A. M. A. 126:1059 (Dec. 28) 1944.

During immobilization, atrophy of the quadriceps muscle group develops rapidly from disuse. This group extends and stabilizes the knee; its strength is one of the key factors in standing and walking. The vastus medialis muscle becomes disproportionately more atrophied than other components of the quadriceps group during immobilization. This muscle required special attention because it is concerned chiefly with the last 15 degrees of extension. It is exercised only by complete knee extension. The gluteus muscles also were given early and continuous setting exercises. These muscles are important in pelvic movements and stabilization of the hip during walking; when weak, they cause a characteristic limp. Strength of the dorsiflexors of the foot, especially the tibialis anticus muscle, had to be maintained by early active and graduated movements against resistance to combat the danger of a shortened achilles tendon. Exercises of the flexors of the toes and the tibialis posticus muscle during immobilization for femoral fractures were active and resistive.

The Pearson knee attachment permitted early movements of the knee in case of a fractured femur. The patella was kept mobile by manipulation. In general, early and continued attention was necessary in case of fracture of the femur to maintain the extensor muscles — gluteus, quadriceps and tibialis anticus — and to maintain mobility of the toes, ankle, patella, knee and hip.

Fractures of Vertebral Column Without Cord Injury. — Motor vehicle, tank and airplane accidents and strenuous training activities in the armies of World War II contributed heavily to the incidence of compression fractures of the spine without injury to the cord. Proper management of these injuries included early and continued therapeutic exercises; when these were used properly, they helped to return as high as 70 per cent of the patients to their duties. End results depended on the rapidity and completeness of reduction, the adequacy of immobilization and the therapeutic exercises used. The orthopedic surgeon reduced the fracture as early as possible and fixed it in a hyperextension body cast, which was worn, depending on the severity of the fracture, from four to six months. Therapeutic exercises were begun early and gradually increased to prevent atrophy and weakness, especially to the extensors of the back, and to prevent adhesions from forming between muscle layers during immobilization. After removal of the cast, postural and mobilizing exercises eradicated residual pain and stiffness of the back. The psychologic effects of early and constant exercises upon the patient were important; his fear of a broken back was abated. Flexion exercises of the involved vertebrae had to be avoided.

In general, the exercises for fractured backs were those proposed by Böhler, with some modifications. Pusetz and Thompson have published a description of those used at Hammond General Hospital.[4]

The exercises for immobilized fractures of thoracic and lumbar vertebrae used by me were the following:

1. The patient carried relatively light sandbags on the head. This exercise was instituted with a 1 pound bag when the patient was first seen in the clinic of the department of physical medicine. The weight was gradually increased to 5 pounds.

2. Straight leg-raising exercises were given for the first week. First one leg was raised, then the other and finally both. It was not necessary to repeat the exercise more than twenty times. The difficulty of the exercises was graduated by changing the speed of the motion. At times this exercise was modified by having the patient also hyperextend the trunk and extend the hips.

3. The patient lay on his back with his extremities held fast to the treatment table and then slowly raised his trunk from the plinth. This exercise was gradually

4. Pusetz, M. E., and Thompson, I. E.: Physical Therapy in Compression Fractures of the Spine, Physiotherapy Rev. 24:51 (March-April) 1944.

increased in number of repetitions until the patient was doing it twenty times a session, and the speed was also increased as the patient became stronger.

4. The preceding exercise was followed by one in which the trunk extended beyond the plinth. At the start of the exercise the patient's head touched the floor, and at the conclusion of the movement the patient was in sitting position. The legs, of necessity, had to be held fast to the table during this maneuver.

5. The patient lay prone with his legs held firmly to the table and the torso extending over the edge. At the start the forehead touched the floor; at the conclusion the hips were hyperextended.

These exercises were cumulative, and each patient who was able to do so did all the maneuvers at each session to the limit of his capabilities. Two sessions were given each day.

Transplants. — In some patients with war injuries, soft tissue damage necessitated muscle transplants to restore usefulness to some of the injured extremities. Therapeutic exercises were undertaken as soon as possible after operation to train the transplanted muscles in their new functions. At the very onset it was necessary to impress on the patient the need for coordination of muscle action to obtain the desired movement. In case of fractures early exercises were designed to achieve or maintain strength; in case of muscle transplants restoration of strength had to be subordinated to development of new function, lest undue strength of a muscle result in improper coordination and distortion of movement. The transplanted muscles literally had to give up their old patterns of coordination and be taught how to work as members of new groups to perform new movements. In such cases patience and care were required in the early exercises to teach transplanted muscles when to contract. Coordinaton of movement rather than active vigorous contractions was emphasized. At first, passive and guided movements were performed with limited range of motion and accommodated to the individual needs, and they were performed slowly. Overcorrection of the deformity had to be avoided. Only after correct function of the transplanted muscle was obtained were efforts made to increase strength. The resistance used in such cases was never more than that which the transplanted muscles could overcome. Too much resistance would have evoked the help of accessory muscles and would have led to substitutions.

Peripheral Nerve Injuries. — The need for early and continued physical therapy, particularly therapeutic exercises, in cases of peripheral nerve injury was emphasized early in the war. Col. R. Glenn Spurling, Consultant in Neurosurgery, in discussing peripheral nerve injuries in the European Theater of Operations,[5] stated that for best results in neurosurgery it is essential that physical therapy be employed before and after operation. He pointed out that functionally useless extremities result if temporarily denervated muscles are permitted to become irreversibly atrophied or fibrosed or if the joints of the wrist, hand, fingers, ankles or toes are frozen beyond repair. He asserted that the excellent results obtained by the peripheral nerve injury program in the European Theater of Operations were due, at least in part, to the expansion of the Physical Medicine Service, which, he said, became one of the most important departments of every neurosurgical center.

The essential features of the management of peripheral nerve injuries were early nerve suture, judicious and proper immobilization and preoperative and postoperative physical therapy. During the preoperative and postoperative periods in which there was flaccid paralysis, heat and massage or whirlpool bath, electrical stimulation and passive exercises were routinely utilized in almost every neurosurgical center. Of necessity, the therapeutic exercises had to be passive. The patient was taught early how to remove

5. Spurling, R. G.: Peripheral Nerve Injuries, J. A. M. A. 129:1011 (Dec. 8) 1945.

his splint and do the exercises several times a day himself. This training was done prior to surgical repair if the operation was delayed more than a few days. As soon as postoperative healing occurred and no danger of tearing or stretching the sutured nerve existed, passive exercises were resumed. When voluntary control began to return, assistive and resistive active motion was started. After the return of voluntary power, coordination and strength were sought. Occupational therapy was particularly important for patients with nerve injuries involving the hand and forearm.

Amputations, Spinal Cord and Brain Injuries. — Therapeutic exercises were valuable for patients with amputations and with spinal cord or brain injuries. The Army raised the management of amputees to new high standards. A series of films on amputations, produced by the Army, is now available. A War Department Technical Manual[6] completed in June, 1946, gives detailed descriptions of the exercises and of the management of patients who have lost one or both lower extremities.

Serious efforts were made to meet the emotional needs of the severely wounded patients and to make clear to them why they needed exercises to enable them to get well. Films to build up the morale of the amputees and the patients with spinal cord injuries were produced and shown to help them to combat their fears and anxieties for the future. Higher morale meant better patient cooperation in the exercises. Exercises for patients with cerebral injuries were based on technics developed by Winthrop Phelps, of Baltimore.[7] The motor disturbance most commonly encountered was spasticity, since Area 6 of the brain was the most frequent site of injury in persons who survived. Occasionally superimposed cerebral flaccidity from injury to Area 4 was also observed. I encountered relatively few persons with athetosis and none with ataxia from battle wounds.

The type of motor disturbance determined the type of exercises administered. Spastic patients needed training in reciprocation; patients exhibiting athetosis were taught relaxation and motor patterns that permitted accomplishments of movement with minimum expenditure of energy. Psychologic management, occupational therapy and reconditioning activities were important in helping those with cerebral injuries to improve and to adjust themselves to their future civilian status.

Comment

Therapeutic exercises played a significant role in management of the severely injured battle casualties and, together with other aspects of physical medicine, contributed to the restoration of the war wounded. Medical officers in other services learned to appreciate the value of therapeutic exercises.

Casualties of civilian life deserve the same thorough treatment as was given war casualties. Carefully prescribed, skilfully administered and physiologically sound therapeutic exercises should be available in all civilian institutions. At present they are not. Persons interested in physical medicine have an obligation to raise the standards of therapeutic exercises in civilian institutions to the same levels as prevailed in military institutions. The situation offers an interesting challenge. Successful meeting of this challenge should provide deep satisfaction to civilian physicians and their patients.

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6. Physical Therapy for Lower Extremity Amputees, United States War Department, Technical Manual 8-293, Washington, D. C., Government Printing Office, 1946.

7. Phelps, W. M.: Recent Trends in Cerebral Palsy, Arch. Phys. Therapy 23:332 (June) 1942; Differential Characteristics of Spasticity and Athetosis in Relation to Therapeutic Measures, New York State J. Med. 41:1827 (Sept. 15) 1941; the Management of Cerebral Palsies, J. A. M. A. 117:1621 (Nov. 8) 1941.

Summary

1. The more important principles of therapeutic exercises in the management of war casualties are discussed.

2. Major developments in therapeutic exercises during World War II are outlined.

3. Applications of therapeutic exercises to orthopedic surgery, neurosurgery and thoracic surgery during World War II are outlined.

4. A plea is made to extend the use of therapeutic exercises to the management of patients with injuries incurred in civilian life.

Discussion

Dr. T. L. DeLorme (Boston, Mass): There is not much I can add to Dr. Levenson's excellent paper. I would like to agree with him wholeheartedly in that therapeutic exercises should be given by trained physical therapy technicians since they are a specific treatment.

The only thing new about this is the application in medicine of the weight-lifting principle to rehabilitation of orthopedic patients. The exercises were first used to develop the quadriceps muscle in patients with instabilities due to cruciate and collateral ligament injuries. We had 23 patients with ligamentous injuries. It required about two months of exercise to restore sufficient muscle power to allow these patients unrestricted weight-bearing activities without buckling and without use of the brace. Many of them were wearing Jones knee cages when exercises were begun.

Following application in instabilities, exercises were used in patients with large amounts of muscle atrophy secondary to fractures of the femur. The results in these patients in power and circumference gained were similar to the gains observed in more nearly normal muscles.

We had an opportunity to exercise about 30 chronic polio patients. In most instances there was increase of strength in the exercised muscle, possibly due to the hypertrophy and re-strengthening of the remaining innervated muscle fibers.

The heavy resistance exercises are given once a day five days a week, the length of the workout depending on the number of muscle groups to be exercised. Each muscle group requires about five to ten minutes. Since the exercises are given only once a day, the patients do not become bored. In a few polio patients, we have found that it is probably better to give them every other day, thereby giving the patients an extra day of rest between workout periods.

In heavy resistance exercises the resistance is graded accurately and proportionate to the patient's strength. The resistance increases are based entirely on the 10-repetition maximum.

We have used the program in several hundred patients with fractured femurs, tibias, fibulas, etc. So far, there has been no reason to think the exercises have caused chronic muscle strains or other possibly harmful effects.

I think the place of these exercises is in the hands of the physical therapy technician. It is physical therapy. There is probably a great field for therapeutic exercises in the postwar world, particularly in rehabilitation of industrial accident patients. It should fit closely into the physical medicine department and be a vital part of it.

Dr. Bert A. Treister (Cleveland): Dr. Levenson has presented in detail the many applications of therapeutic exercises in the rehabilitation of the war injured. In my experience at a busy orthopedic center, therapeutic exercise was the most important single agent in physical medicine that aided in the recovery of the injured. Dr. Levenson has rightfully stressed the importance of individualizing treatment for a particular injury. Of interest are the newer contributions of treatment with therapeutic exercise, especially that of heavy resistive exercise. At my station, an extensive trial of this method proved it to be exceedingly valuable. One of the most important of the newer contributions was the employment of therapeutic exercise following chest surgery for the prevention and treatment of spinal and other resulting deformities. Unfortunately, no experience with this treatment in tuberculosis has been reported. It is well known that an otherwise excellent clinical result following thoracoplasty in a tuberculous individual may be marred by the development of a rather severe degree of scoliosis. It would seem logical to conclude that such deformities, in tuberculosis, could be prevented or, at least, minimized by the cautious and judicious employment of therapeutic exercise.

ARCHIVES of PHYSICAL MEDICINE
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.·. EDITORIALS .·.

EXERCISE

Exercise is one of the most important and least spectacular subjects in physical medicine. Although the writings of the ancients show how the various exercises were employed therapeutically in individuals and in groups as in games and sports, it was not until relatively recent times that the work of various investigators particularly the physiologists demonstrated the influence of exercises on bodily function.

The very basic understanding of all that the term exercise includes, is a knowledge of the physiology of muscular tissue. The contraction and relaxation of one individual muscle is coordinated with practically every organ and system of the body. The chemical and physical changes that take place locally and systemically by muscular activity has been the source of much study and considerable controversy. The excellent article in this issue of the ARCHIVES by Elkins and Wakim[1] furnishes a review of the essential information concerning muscle physiology. In the July ARCHIVES OF PHYSICAL MEDICINE on the editorial pages certain effects of muscular activity on various physiologic processes were given. Karpovich[2] gives additional information in his review of the recent studies on exercises. He found that the capacity for work of muscles depended on the size of the muscle and the "increase in work capacity caused by training coincided with an increase in glycogen and creatine content of the muscles." Another factor affecting the work capacity is the temperature of the muscle itself. By raising the temperature of the muscles by a bath or the use of diathermy, the capacity for work was increased. It was also shown that this was not due to an acceleration of circulation, for by warming the legs the temperature of the arms is increased but the work capacity was not altered. Massaging a part did not change the work capacity. He uses a new term "ergogenics" and defines it as "any agent—physical, pharmacological, etc., which causes an increase in work output." Blood circulation was found to vary with the amount of oxygen consumption during exercise and was controlled by reflexes of working muscles rather than the impulses of the cortex. All such studies are valuable and have practical application.

With a thorough knowledge of the anatomy and physiology of muscle, exercises may be properly prescribed for the various dysfunctions of the body. This ranges from local disorders to general activity. The literature on the local effects of muscular movement both in the muscles themselves and the structures associated with the local action such as joints, tendons, nerves, etc., is extensive. Gellhorn[3] in this issue of the ARCHIVES demonstrates the importance of detailed study of a specific problem. During the past year the ARCHIVES OF PHYSICAL MEDICINE has published other papers giving evidence of what can be accomplished by concentrating on a particular phase of local exercise.

1. Elkins, Earl C., and Wakim, Khalil G.: The Physiologic Basis for Therapeutic Exercise, Arch. Phys. Med. 28:555 (Sept.) 1947.
2. Karpovich, P.: Ann. Rev. Physiol. Stanford University, Calif., Am. Physiolog. Soc., Vol. 9, 1947, p. 149.
3. Gellhorn, E.: Patterns of Muscular Activity in Man, Arch. Phys. Med. 28:568 (Sept.) 1947.

Exercises are not only valuable for local dysfunction but for many diseases and disorders. Huddleston[4] proves what careful and comprehensive exercises can achieve in the tuberculous patient. As Huddleston states "it is the integrated therapy regimen" which is capable of unusual results. As he shows, planned exercises in chest cases both pre and postoperatively not only prevent the complications of surgery which alone would justify their use but secure a speedier and more satisfactory rehabilitation of these patients. The use of purposeful and physiologic general exercises have been found beneficial in relieving symptoms and at times aiding in the cure in such conditions as the numerous cardiac diseases, peripheral vascular disorders, pelvic disturbances, neuroses, chronic arthritis of different types and others.

Rehabilitation is also included in the realm of general exercises. Clinically the advantages of rehabilitation and reconditioning were dramatically proven during the war. Levenson[5] reviews the results of such a program in the army and Rusk[6] emphasizes the possibilities of extending rehabilitation to centers in civilian practice. Obviously no plea should be necessary.

The subject of exercise is not complete unless physical training is considered. During any emergency such as a war much attention is directed towards physical fitness not only for the members of the armed forces but for many civilian employees as well. In peace time periodic waves of enthusiasm for exercising occur infecting a few of the sane and more of the near insane. Health clubs of one type or another are patronized by a few individuals and at all times a certain percentage of both men and women of every age engage in sports or other strenuous exercises not only because of the pleasure attached to such activities but with the hope that they will be aided physically. In most schools and colleges some form of physical training or physical education is included in the curriculum and a student, unless excused, must complete a required number of hours before he is graduated. In the state of New York, a law, although not strictly enforced, directs that a prescribed number of hours each week through the twelve elementary grades be devoted to such a program. The work usually consists of formal calisthenics and sports and games with one of its purposes of engendering good health. The best developed athlete is the one most envied and is often considered the most healthful.

The entire problem of exercises in whatever form in physical training needs further scientific study. Just what influence do physical exercises have on the development and coordination of the human body or on mental and emotional equilibrium? Do certain exercises or sports achieve better physical efficiency than others? One of the chief beneficial aspects of physical training for many individuals is psychologic which is important. But what proof is available that these measures are the most efficient or effective means of maintaining healthy human beings? Are there certain dangers in overzealous or misdirected efforts not only immediately but in the future lives of these individuals? Do the persons who perform hard manual labor enjoy better health? Actually what is the measure of good health? Freedom from disease or disability? These are merely a few trite questions and could be expanded to include many phases of the problem. A group of physical educators may be quoted as follows,[7] "these results (students inability to perform certain physical tests) give genuine concern for the health

4. Huddleston, O. L.: Reconditioning for Tuberculous Patients. With Special Reference to Those Requiring Thoracic Surgery, Arch. Phys. Med. 28:575 (Sept.) 1947.
5. Levenson, C. L.: Therapeutic Exercises in Management of War Injuries, Arch. Phys. Med. 28: 584 (Sept.) 1947.
6. Rusk, H.: A Community Rehabilitation Service and Center, Arch. Phys. Med. 28:582 (Sept.) 1947.
7. National Research Council, Washington, D. C.: Endurance of Young Men, Monograph of the Society for Research in Child Development, 1945.

and physical fitness future of the men. Large numbers of young men are entering adult life unconditioned and unmotivated to do the physical labor necessary in life or to maintain physical fitness. This trend undoubtedly contributed greatly to high accident rates, rapid loss of health after the age of 30, and widespread chronic disease because of the lack of a positive and dynamic preventive program of conditioning hygiene." A member of the Board of Education of Rochester, N. Y., remarks,[8] "human beings of all ages must have healthy bodies and minds and a capacity for great endurance if they are to be successful in life." This point of view seems to be basic to the very existence of a progressive democracy and is generally accepted by all thinking people." A physician[9] interested in physical education has this to say, "the universal but unjustifiable faith in physical training as a primary promotor of health is dangerous. There is much evidence that this erroneous belief has in the past done a great deal of harm. Physical training cannot promote general health; health must be attained through a medical system. While poor health frequently impairs physical efficiency, a low standard of physical efficiency does not necessarily indicate illness; nor does even the highest possible level of athletic prowess prove freedom from disease."

In endeavoring to answer these questions the Europeans, particularly the Germans who had been strong advocates of an extensive program of physical culture for the population generally, published several articles before the war attempting to be more objective about gymnastic work and training methods and articles have appeared in the American journals from time to time, but further investigations are necessary. It is because of the possibility of influencing health either beneficially or adversely that the medical profession should show concern in these programs. Physicians have shown too little interest and even less control. Logically the physiatrists should develop the most vigilance and be the best informed.

Thus the physiatrists and those interested in the field of physical medicine, in order to have a true understanding and appreciation of the scope of exercise, must begin with a knowledge of the activity of an individual muscle fiber and all the physiologic processes that are thereby activated, realize the usefulness of local measures for specific effects and potentiality of the more general therapeutic exercises for the wide variety of diseases and disorders, influence and contribute to a wider application of reconditioning and rehabilitation and finally recognize the medical aspects of physical training and all its methods, be able to evaluate its accomplishments and assume a more active share in its supervision.

8. Norton, H. J.: Physical Fitness, J. Health & Phys. Educ. 18:383 (June) 1947.
9. Jokl, E.: Medical Theory of Gymnastics, Clin. Proc. 2:1 (Jan.) 1943, (in summary, Kovács, R., editor, Year Book of Physical Therapy, Chicago, Year Book Publishers, Chicago, 1943).

HISTORY AND DEVELOPMENT OF PHYSICAL MEDICINE *

JOHN S. COULTER, M.D., CHICAGO.

Physical medicine developed in World War I as physiotherapy. Physical medicine is not a new concept of medical practice. Primitive man used sunlight for healing, he bathed his wounds in water, he recognized the efficacy of massage and the benefits of exercise. But it is thought that physical medicine's history and development can be traced from World War I to World War II.

Influence of the Medical Profession

The medical profession with a few exceptions did not know the value of physiotherapy, as it was then called, before World War I. Col. Joel E. Goldthwait, Boston, was in charge of Orthopedic Surgery of the American Expeditionary Forces. Col. E. G. Brackett of Boston in The Surgeon General's Office of the Army in Washington was in charge of Orthopedic Surgery in the United States. Assisting him was Major Paul B. Magnuson. Col. Frank Billings of Chicago was head of the Division of Physical Reconstruction; Col. Harry Mock was his assistant and later head of this division. Dr. Frank B. Granger who was using physical therapy in Boston City Hospital at the time World War I developed, was given charge of physical therapy here and abroad. These doctors saw in physiotherapy an adjunct to medicine and surgery to rehabilitate wounded soldiers as quickly and as surely as possible.

Dr. Granger developed the work of physiotherapy in army hospitals to such an extent that by the time the emergency was over, physiotherapy had gained a respectable place and by his efforts only women of high quality were accepted in the service. Through his efforts, physical therapy was even then becoming a profession which demanded adequate training. Dr. Granger in 1926, became the first physician specializing in physical therapy to become a member of the Council on Physical Therapy of the American Medical Association.

Dr. Paul B. Magnuson, recognizing the value of this branch of medicine, in 1919 was instrumental in establishing a Physical Therapy Department at Wesley Memorial Hospital of Northwestern University Medical School, which in 1927 developed a teaching course for physical therapy technicians.

Dr. Harry Mock developed a physical therapy department at St. Luke's Hospital, Chicago, when he returned home from the war in 1920. In 1926, he became the first chairman of the Council on Physical Therapy of the American Medical Association.

Dr. Joseph F. Smith of Wisconsin realizing with many others of the profession, the deplorable condition existing in 1925 brought a resolution before the House of Delegates of the American Medical Association in May of that year, urging the Board of Trustees to establish a Council on Physical Therapy. The resolution was adopted and the Board of Trustees at its meeting the following September created the Council. In 1944, the Board of Trustees on the suggestion of the Council, changed the name to Council on Physical Medicine.[1]

There are two societies of physicians interested in physical medicine. First: The American Congress of Physical Medicine. Its most important works are the publication of the *Archives of Physical Medicine* and the organization of the American Registry of Physical Therapy Technicians. Physicians to become members have to be members of the American Medical Association, their county medical societies or members of a government service.

Second: The Society of Physical Medicine. To become a member, a physician must be on the staff of a recognized hospital or on the staff of a medical school and have specialized in physical medicine for five years. There are 113 members of the Society.

The National Foundation for Infantile Paralysis has greatly aided the progress of physical medicine. Its activities were made possible by the generosity of the American people through the annual March of Dimes. A value of their efforts for physical medicine can be seen from the following, a part of their report of this their tenth fiscal year:

Scholarships for Physical Therapists	$1,344,369.53
Assistance to Profession Associations in Physical Therapy	69,597.00
Teaching Programs in Physical Therapy and Physical Medicine	994,798.30
Research in Physical Medicine	806,690.00
Grand Total	$3,215,454.83

Miss Catherine Worthingham, a physical therapist, is the Director of Professional Education.

Bernard M. Baruch in memory of his father Dr. Simon Baruch, gave $1,100,000 for physical medicine. Dr. Frank Krusen is director of this committee. Columbia University was given $400,000; New York

* Read at the First Annual Session of the Association for Physical and Mental Rehabilitation, Chicago, June 5, 1947.

1. Council on Physical Medicine, Handbook of Physical Medicine, Chicago, American Medical Association, 1945.

University $250,000; and the Medical College of Virginia $250,000. A group of selected medical schools were given $100,000 and $100,000 was used for fellowships or residencies in physical medicine.

The American Registry of Physical Therapy Technicians which is sponsored and controlled by the American Congress of Physical Medicine abides by the minimum requirements as set forth by the Council of Medical Education and Hospitals of the American Medical Association for training in physical therapy. In February, 1935, the American Registry of Physical Therapy Technicians was organized and the first examination was given in September of that year. In June, 1936, thirty-one certificates were issued to the first registrants. In 1947, there were a little over 4,000 registrants.

Influence of the Physical Therapists

During World War I, there were slightly less than eight hundred Reconstruction Aides in Physiotherapy in service, almost three hundred of whom were overseas. Marguerite Sanderson from Dr. Goldthwait's office in Boston was chief aide immediately under Dr. Granger. She began her work in The Surgeon General's office but later was sent to France to take charge of the work abroad.

At the outbreak of the war, there were no schools of physical therapy or even short courses but very soon several courses were established. The students accepted were chiefly teachers of physical education who already had some background in anatomy and allied subjects or they were graduates of physical education schools. The first physical therapy course organized was at Walter Reed Hospital, but because this course could not supply all the needs, a request was sent to a number of colleges and schools of physical education to assist in training aides. Fourteen institutions established courses to meet the requirements outlined by The Surgeon General's Office, the largest of which was Reed College in Eugene, Oregon. Mary McMillan was in charge of this course.

The actual birthplace of the American Physiotherapy Association is a somewhat controversial question.[2] The most convincing records point to Keen's Chop House in New York City where a meeting was held on January 15, 1921. About thirty aides were present and six doctors. The new organization was then known as the American Women's Physical Therapeutic Association. In 1922, the name of this organization was changed to the American Physiotherapy Association so that eligible men could be included in the membership. During the first days of the organization a question arose concerning the admission of nurses who were or had been doing some form of physical therapy in the army or elsewhere. The constitution stated that the applicants must be graduates of recognized physical education schools or physical therapy courses. This eliminated nurses. Perhaps the constitution provided for the admission of nurses with adequate physical therapy training for they became members as early as 1924. The membership at the beginning of 1921 was 245 and in 1947 it is 4,000.

In March, 1921, there appeared a new journal "The Physiotherapy Review," It was a quarterly until 1928, after which time it became a bi-monthly.

The American Physiotherapy Association had been fully aware of its limitations in undertaking the task of raising the standards of its profession by presenting its curriculum to schools and placing its stamp of approval or withholding it. The Association took this burden upon itself only because no other organization had done so, and because it realized the great importance of good schools. However, many physicians specializing in physical therapy, and some of the approved schools raised an objection to the Association assuming the position of an accrediting agency. Such a role, they maintained, should be vested in a more authoritative body. There were physicians who approved the Association's policies and commended it for insisting upon elevated requirements for admission into its ranks. The Association was so anxious to maintain high educational standards in order to better serve the physicians and the patients and so cognizant of its inadequacy to struggle with the complications, that it determined of its own volition to appeal to the American Medical Association to take over the school situation.

Neither the Council on Physical Therapy nor the American Physiotherapy Association had staff members available to inspect schools. Hence it was decided that the Council on Medical Education and Hospitals because of its experience in this class of work, should undertake this survey and permanently maintain the list of approved schools.

On the recommendation of the Committee on Education of the American Physiotherapy Association in 1934, a bill was introduced in the House of Delegates requesting the American Medical Association to establish standards and inspect and rate schools for physical therapy technicians. This work was assigned to the Council on Medical Education and Hospitals by the Board of Trustees.[3]

2. Hazenhyer, J. M.: A History of the American Physiotherapy Association, Physiotherapy Rev. 26, Nos. 1, 2, 3 and 4, 1946.

3. Anderson, O. N.: Educational Standards for Physical Therapy Technicians, Arch. Phys. Therapy 7:615 (Oct.) 1936.

Obviously, time does not permit inclusion of the Essentials of an Acceptable School for Physical Therapy Technicians as developed by the Council. Copies of these essentials and reprints of the list of acceptable schools may be secured on request from the American Medical Association, 535 N. Dearborn Street, Chicago.

History is made every day. I would like to close this paper with an historical thought made in 1947. We had a notion to put a physical educator into a hospital in Chicago, where the superintendent was a former director of physical education in a city just outside of Chicago. He was not a physician. I wrote to Dr. Earl C. Elkins, Chairman of the Educational Committee of the American Congress of Physical Medicine and on the Committee on Implications of Reconditioning for Physical Education appointed by the Therapeutic Section of the American Association for Health, Physical Education and Recreation. He wrote in part as follows:

"In answer to your question concerning the use of physical educationalists in civilian hospitals, I think that if it is allowed at the present time it will be a dangerous procedure. You and others have fought for years to raise and maintain the standards for physical therapy technicians. I cannot see how hiring physical educationalists, even though experienced in the Army, can do anything but lower standards markedly and ultimately damage the technical field immeasurably. One has to realize why the present trend exists. It is because of the war and the urgent necessity for personnel, even though poorly trained, and because of an ignorance on the part of many medical men, some very prominent, as to what constitutes therapeutic exercise."

At a meeting in New York, the Committee on Physical Reconditioning of the American Association of Health, Physical Education and Recreation went on record as saying that physical educationalists should not go into the field of therapeutic exercise; that is they should not start their programs with the patient until physical treatment is ended — in other words not until the patient has been dismissed from the care of a physician. When talking to some of these men of high authority who are well trained and who have had a lot of experience in reconditioning, they say that they are perfectly willing to go along with our way of thinking being very careful as to what the physical educationalist does until definite standards are agreed upon by the medical profession.

History shows us that the Association for Physical and Mental Rehabilitation should agree with H. Harrison Clarke, Director of Graduate Study of Springfield College, Springfield, Mass., and Chairman of the Committee on Implications of Reconditioning for Physical Education of the American Association for Health, Physical Education and Recreation when he says that there are two major problems which are faced by the committee. First, a careful definition of the physical reconditioning field as it is now developing after the war, and second, the need for establishing appropriate training standards in this field to be developed in cooperation with medical groups.

MEDICAL NEWS

Dr. Kovacs Honored

The Section of Physical Medicine of the Royal Society of Medicine of London at their meeting on June 11, 1947, elected Richard Kovacs of New York City an honorary member in recognition of his distinguished services to science and declared him to be entitled to all the privileges of such honorary membership.

Dr. Ivy at Nuremberg

Dr. Andrew C. Ivy, vice president of the University of Illinois, spent three weeks in Nuremberg, Germany, where he served as adviser at the trials of Nazi doctors charged with crimes of a medical nature, serving as a special consultant to the secretary of war. Dr. Ivy has made two previous trips to Nuremberg, having served as the United States representative on an international commission which investigated Nazi human experiments July, 1946 and having testified on the ethical principles of medical investigations, studies and experiments conducted by Nazi doctors on trial last January.

A Seminar on the Progress of Physical Medicine in New York

The New York Polyclinic Medical School and Hospital, the pioneer postgraduate institution of the United States announces plans for a Seminar on the Progress of Physical Medicine, on December 1st, 2nd and 3rd.

Members of the Faculty and invited guests will give talks and demonstrations on the progress in methods, clinical application, and in related fields, especially medical rehabilitation. The Seminar will be conducted by Dr. Richard Kovacs, Professor of Physical Medicine and his staff. The preliminary program can be obtained by writing to the New York Polyclinic Medical School and Hospita, 345 West 50th Street, New York 19, N. Y.

A Third Seminar on Physical Medicine at Galveston

The Medical Branch of the University of Texas is arranging the holding of the third seminar of physical medicine at Galveston during the first week of March, 1948. Judging from the interest shown in the preceding two seminars and remembering the cordial hospitality of the medical faculty at Galveston, physicians and physical therapists not only from the Southwest but from all parts of the United States will undoubtedly want to enroll again in large numbers. For further details address Dr. W. A. Selle, Professor of Physiology, University of Texas, Medical Branch, Galveston, Texas.

Scholarships for Training in Cerebral Palsy

Alpha Chi Omega, national women's fraternity, and the National Society for Crippled Children and Adults, the Easter Seal agency, has joined forces to supply therapists and specially trained physicians to treat cerebral palsy cripples, Mrs. Darrell Nordwall, of Larchmont, N. Y., fraternity vice-president, has announced.

Over 700 members of the fraternity, at its 26th annual convention at Chateau Frontenac, Quebec, voted to give $5,000 yearly for schdlarships to the National Society's Cerebral Palsy Division, which is directed by Miss Jayne Shover. Lawrence J. Linck is executive director of the organization.

Graduate scholarships will be given to physicians, therapists, and special educators. The allotment will cover maintenance and tuition for study at a recognized training center for a minimum of three months.

Recipients of the scholarships will be selected by the National Society's cerebral palsy medical advisory committee, and the Cerebral Palsy Service. Mrs. Ivan L. Willis, Flossmoor, Ill., will represent Alpha Chi Omega national council on the board. Authorities on the medical advisory council include Winthrop M. Phelps, M.D., Baltimore, Md.; Earl R. Carlson, M.D., Pompano, Fla.; Bronson Crothers, M.D., Boston, Mass.; George G. Deaver, M.D., New York, N. Y.; Temple Fay, M.D., Philadelphia, Pa.; Meyer A. Perlstein, M.D., Chicago, Ill.

Dr. Valentine Welcomes Congress Members to North Platte

Dr. L. F. Valentine of 204 West 5th Street, North Platte, Nebraska cordially invites any member of the Congress to stop off at North Platte to see what he is doing in physical medicine. North Platte is one of the stops on the transcontinental airlines as well as on Lincoln Highway number 30.

Army Engineers to Build Greatest Medical Center

What is planned to be the greatest medical research center in the world will be built at Forest Glen, Maryland, by the Corps of Engineers for the Office of The Surgeon General, according to a recent announcement made by Major General Raymond W. Bliss, The Surgeon General. In keeping with technologic advances in all fields, based on experiences in the late war, the center will be equipped to anticipate and meet the medical problems of the future as well as to cope with those of the present. The initial cost is estimated at approximately $40,000,000. Construction will be supervised by the District Engineer, Washington, D. C. Engineer District.

BOOK REVIEWS

BIOELECTRIC FIELDS AND GROWTH. By *E. J. Lund,* Professor of Physiology and Director of the Institute of Marine Science, and Collaborators, Laboratory of Physiology and Biophysics, the University of Texas. With Bibliography of Continuous Bioelectric Currents and Bioelectric Fields in Animals and Plants, by *H. F. Rosene,* Associate Professor of Physiology, University of Texas. Cloth. Price, $6.00. Pp. 391, with 74 illustrations. Austin, Texas, the University of Texas Press, 1947.

The extensive work of Lund and his collaborators at the University of Texas has so far been published only in the form of scientific papers. The authors have now collected much of this material, together with some unpublished material, in this book. Added to it is a bibliography on the effects of constant bioelectric currents which includes over 1,400 references. To many of us electro-physiology has always meant the physiology of neuromuscular excitation and the physiology of resting and action potentials of nerves. The work on constant electric fields on growth phenomena is equally important and has attracted much less attention. The present author and his collaborators have contributed a great deal to this field. Out of their experience has grown this most challenging book. Five sections of the book cover the detailed experiments while section 6 is a general discussion of the results and their significance.

The book starts out with a discussion of the electric field of the cell and cell aggregates. Simple but well thought through apparatus has been described. The second section covers an analysis of the effect of gravity on the electric correlations field. While the third section discusses spontaneous variations in the electric field of plant roots, in section four the bioelectric field and polar growth is discussed under the influence of outside electric fields. This section contains an interesting chapter on polarizable and non-polarizable electrochemical systems in the cell and another chapter on inhibition of polar growth by applied electric current. Section five deals with biocoulometry This contains a most challenging chapter on the efficiency of polar epithelial membranes in generating electrical energy. The book contains a wealth of information in fundamental cellular physiology as related to constant electrical fields.

The physician might ask the question, what the importance is for the treatment of patients of experiments performed on plants and plant cells. It is good to remember that the present authors are dealing with fundamental biophysical phenomena. These phenomena are as important in the growth of plants as they are for a fundamental analysis of the biophysical problems in animals and man. And it should be remembered that such problems as nerve regeneration and normal and abnormal growth in human beings will benefit a great deal from fundamental research such as recorded in this book. The senior author stresses in his conclusions the fact that the existence of an electric polarity of the structure in polar cells and the resulting bioelectric field brings into relief the fact that there must exist in such polar cells an oriented electrochemical reaction system. It is clear then that the influence of outside fields on such a polarized system should lead to very interesting scientific conclusions.

This book does not go into the clinical application of these fields but for those of us who are interested in the fundamental processes of biophysics, this book is an extremely valuable contribution.

MEDICAL EDUCATION AND THE CHANGING ORDER. By *Raymond B. Allen,* M.D., Ph.D. Executive Dean, College of Dentistry, Medicine and Pharmacy, University of Illinois, Chicago. Cloth. Price, $1.50. Pp. 136. New York: The Commonwealth Fund, 1946.

This is a monograph issued under the auspices of the Committee on Medicine and the Changing Order which was established by the Council of the New York Academy of Medicine.

The author shows the evolution of medical education in this country and how it has been influenced by various factors. In the discussion he recognizes the early training of a doctor even before his entry into a medical school for as he states "the responsibility for well rounded expression and development rests squarely on the home, the church and the school." He points out rather pertinent faults in the premedical schools and colleges among which is their emphasis on the biological and physical sciences "to the exclusion of disciplines in other fields such as the social sciences and humanities." In the chapter on Graduate Medical Education he has several ideas about specialization. He believes that the need for specialists is for the diagnosis and care of the many unsolved problems, but as these become less complicated and better understood the necessity for experts becomes less, too. The use of effective drugs such as the antibiotics and other chemotherapeutic agents has simplified the care of many patients and since their use is within the realm of the family practitioner the influence of the specialists may diminish. To be sure the problems to be solved are much too numerous as yet to believe that clinical specialty is indispensible but as he shows the trend may eventually be away from rather than towards specialization as it certainly is today.

The last chapter is entitled "Problems and Opinions." Here the author discusses such topics as faculty, dean, student body, curriculum, examinations, etc., with frankness and understanding. The solution to the problems are not simple but the author has the courage to point out some of the defects and offers suggestions for their improvement. Physical medicine is referred to occasionally, for example "research in the important field of physical medicine including occupational therapy will broaden and strengthen many empirical methods about which not enough is known scientifically."

The author has made a notable contribution in this series of monographs. This book should be read by all medical school deans and all persons who are responsible for policies in medical schools. They may not agree with everything but the reading cannot help but be stimulating.

ESSENTIALS OF MEDICINE. By *Charles Phillip Emerson, Jr.*, A.B., M.D., Assistant Professor of Medicine, Boston University School of Medicine, and Associate Member Robert Dawson Evans Memorial and Massachusetts Memorial Hospitals, and *Jane Elizabeth Taylor*, R.N., B.S., M.Ed., Nursing Education Consultant, U. S. Public Health Service. Fifteenth Edition. Cloth. Price, $3.50. Pp. 688 with four colored plates and 612 figures consisting of graphs, photographs and drawings. Philadelphia, London and Montreal: J. B. Lippincott Company, 1946.

The fact that this is the fifteenth edition of this volume is adequate testimony to its value as a teaching text in medicine for nurses. The present edition has been revised and brought up to date by the addition of new material on chemotherapy, blood and blood substitutes, the deficiency states and much other new data in various fields of medicine. There is a new chapter on "Neoplasms" and an entirely new unit on therapy, prevention and nursing care. The presentation is clear and concise and the material is well organized.

The text is divided into thirteen units and each unit is further divided into chapters numbering thirty-two in all. The titles of the units are as follows: (1) Introduction to nursing care; (2) diseases of the organs of respiration; (3) the organs of circulation and their diseases; (4) the alimentary system; (5) the urinary tract; (6) the integumentary system; (7) allergic conditions; (8) the endocrine glands and metabolism; (9) the nervous system; (10) the musculoskeletal system; (11) the reproductive system; (12) the communicable diseases; (13) psychoneurotic reactions; and (14) nursing procedures in diseases prevention and treatment. The presentations of the diseases of the various systems are preceded by anatomical and physiologic discussions. Each unit is completed by a comprehensive bibliography. Unit 14 is made up of outlines of nursing procedures, prevention and treatment of diseases discussed in the previous units of the text. The main headings in these outlines are: (1) Pathology; (2) principal treatments; (3) nursing care; (4) review; (5) public health and prevention. Throughout the volume also are scattered discussions of nursing care.

A textbook so well and favorably known as the present one needs little recommendation. It appears to the reviewer to be an excellent medical text for use in schools of nursing, either as the main teaching text or as a reference work.

VISUAL OUTLINE OF PSYCHIATRY. By *Leland E. Hinsie*, M.D., Professor of Psychiatry, College of Physicians and Surgeons, Columbia University, New York; Assistant Director, New York State Psychiatric Institute and Hospital. Third Printing. Price, $2.00. Pp. 107. Cloth. London, New York, Toronto: Oxford University Press, 1941. Third Printing, 1946.

Hinsie's concise volume offers an excellent scheme of orientation regarding the central facts relating to the mind or psyche. The psyche, although it has its own embryology, anatomy, physiology and pathology, cannot be regarded as an isolated organ, for its function is related directly or indirectly to all tissues of the body. The contents of the presentation include I. Mental hygiene; II. Organization of the mind; Definition; The psyche; Form of psyche; Functions of the psyche; Résumé; Other systems; III. Psychiatric syndromes; Definition; General incidence; Psychoneuroses; Sexual psychopathies in general Psychopathic personality; Psychoses; Psychoneuroses with organic pathology; Organic pathology and Psychiatric states; Psychiatric and social states; Mental problems in childhood; IV. Intellectual deficiency. An extensive glossary and index completes the practical and authoritative volume and three printings within four years testify not only to its welcome acceptance by students of medicine but also to that of modern psychiatry in particular.

THE HUMAN FRONTIER: A New Pathway for Science Toward a Better Understanding of Ourselves. By *Roger J. Williams*. Cloth. Price, $3.00. Pp. 314. New York: Harcourt, Brace & Company, 1946.

This is a semi-popular book on a new branch of applied science by Dr. Williams, biochemist and a scientific discoverer on his own — he discovered and synthetized pantothenic acid, one of the B-vitamins. The author contends that so far as our scientific utilization of human resources is concerned, we are in the ox-cart days, and pleads eloquently for the development of the science of "humanics" which denotes comprehensive study of individual human beings. The investigation of man, he contends, has fallen short of its goal because it has been in the hands of specialists, each working within his own narrow field, and he believes that what is needed today is a new type of specialist who will devote himself to new coordinated interest and attention to the comprehensive study of actual individuals. After the introductory on the urgency of the new science the author develops his theme in 16 chapters:

Fundamental metabolism as it is related to character traits; sense of sight and social behavior; traits based on other senses; other physiological traits; endocrine glands and behavior; psychological traits and capacities; man and society; humanics — tolerance — mental hygiene — religion; humanics and education; marriage; criminology; medicine and medical research; heredity and environment; humanics and leadership; humanics and employment and international relations. All these chapters are well decumented and are written with an excellent appreciation of the physiologic, psychologic and social aspects involved. Here is a book which is indeed trail blazing and should be of extreme interest to all philosophically and scientifically minded.

DEVELOPMENTAL ANATOMY. A TEXTBOOK AND LABORATORY MANUAL OF EMBRYOLOGY. By *Leslie Brainerd Arey,* Ph.D., Sc.D., LL.D. and *Robert Laughlin Rea,* Professor of Anatomy, Northwestern University. Fifth Edition. Cloth. Pp. 616, with 588 figures. Price, $7.00. Philadelphia: W. B. Saunders Company, 1947.

The new edition of this textbook of developmental anatomy has brought up to date the extensive literature in the field of embryology since the previous edition in 1940. The first portion of the text deals with general developmental principles and has been wholly rewritten and reorganized. Most revisions are found in that portion of the text dealing with growth, histogenesis and early human embryologic development. Many new illustrations clarify the complex subject of the morphologic changes at each stage of embryologic development.

The remaining two-thirds of the book deal with special developmental anatomy of various bodily systems and organs and a laboratory manual of embryology. These portions have had a few minor corrective changes but no essential differences are found in comparison with the previous edition. This book remains as a splendid reference book for all physicians and a standard text for the student of embryology.

NOTES ON NURSING: WHAT IT IS, AND WHAT IT IS NOT. By *Florence Nightingale,* London, 1859, Harrison, 59 Pall Mall, Booksellers to the Queen. Reproduced in facsimile by J. B. Lippincott Company. Price, $1.25. Pp. 79. Cloth. Philadelphia, London and Montreal, 1946.

Nearly a century has passed since the unforgettable Florence Nightingale, a woman of great vision and wide experience, wrote her message to the womanhood of the world. To make available this first book on nursing, the original English edition has been reproduced in facsimile in 1946, eighty-seven years after its first issuance. The timeliness of the revival of "Notes on Nursing," the plan and purpose of which is so clearly stated in Miss Nightingale's preface, cannot be questioned. It is a stimulating experience to read over almost a hundred years after her first publication, the basic discussions of bedside nursing in such chapters as Ventilation and warming; Health in houses; Noise; Taking food; Observation of the sick, etc., and epitomized in terse, sometimes caustic but always convincing language. In a foreword to this reproduction, Annie W. Goodrich states, "Though the message of this little book is for all, to none should its appeal be stronger than to the American nurses of the twentieth century who, as teachers, as citizens and ofttimes as mothers, have through their acquired knowledge, the responsibilities that citizenship in a democracy implies. It is a tragic fact that, despite almost phenomenal advances in the art and science of living, ignorance, poverty and disease still obtain in great degree." This is indeed a book which should be owned not only by every member of the nursing profession, but which should find its place in every home, chiefly because it interprets in single terms the age old principle of healthy living.

PHYSICALLY HANDICAPPED WORKERS: I. EXPERIENCE IN WAR INDUSTRIES; II. REHABILITATION OF VETERANS. By *Ross A. McFarland,* Ph.D., Assistant Professor of Industrial Research, Graduate School of Business Administration, Harvard University. Paper. No charge. Harvard University, Graduate School of Business Administration, Soldiers Field, Boston 63, Mass.

A GUIDE FOR THE PLACEMENT OF THE PHYSICALLY IMPAIRED. Pamphlet No. 14. Pp. 337. Paper. Price, 60c. United States Government Printing Office, Washington 25, D. C.

TECHNICAL MANUAL TM 8-293, PHYSICAL THERAPY FOR LOWER EXTREMITY AMPUTEES, dated 14 June 1946, may be purchased at twenty cents a copy direct from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

MUSICAL SONS OF AESCULAPIUS. By *Willard Marmelszadt;* M.D. Foreword by *Victor Robinson,* M.D. Cloth. Price, $3.00. Pp. 112. New York: Froben Press, 1946.

It is the everlasting credit of the recently deceased Victor Robinson that he encouraged and made possible in recent years quite a number of stimulating monographs on the cultural and historical aspects of medicine. In the foreword of this volume, perhaps one of the last contributions of his prolific pen, Dr. Robinson states that teachers of medicine fail in their fundamental duty if their students only listen and read but remain unproductive. He points to the numerous examples of medical students making notable contributions, not only by medical discoveries but also by their extracurricular activities. The author of this volume, Willard Marmelszadt, as student at Tulane University, attended classes of music and became interested in the contributions that practitioners of medicine had made to the tonal arts. The result was this work which received the Rudolph Matas Award of Tulane University Medical Historical Society, then won the Osler medal of

the American Association of the History of Medicine. The first chapter relates to European physician-musicians in the first nineteen centuries; among these were Paracelsus, who became famous as an organist and composer; Oliver Goldsmith and Laennec who both played the flute; Billroth who was an excellent pianist and an admirer of Brahms, but above all, Berlioz, who became a great composer ("The Damnation of Faust," etc.) and Borodin who composed symphonies and the incomplete opera "Prince Igor," completed later by Rimski-Korsakov. The second and third chapters relate to contemporary European and American physician musicians; among the latter was Leopold Damrosch who abandoned a medical career to become a famous conductor and composer; also John C. Hemmeter, musical writer and composer of hymns, and many enthusiastic lovers of music, such as Arpad G. Gerster, renowned surgeon of Hungarian origin, and the great medical historian, Felding H. Garrison. Dr. Max Thorek was a violinist who obtained student aid in his medical education by becoming a snare drummer in the University of Chicago Band. Among the final chapters of the interesting volume are "Doctor's Symphony Orchestras"; Popular Music, Jazz and Swing and Medical Musical Life in New York. Sixteen full page illustrations add to the attractiveness of this unusual book.

THE USE OF RESEARCH BY PROFESSIONAL ASSOCIATIONS IN DETERMINING PROGRAM AND POLICY. By *Esther Lucile Brown*, Director, Department of Studies in the Professions, Russell Sage Foundation. Paper. Pp. 39. Price, 25 cents. New York: Russell Sage Foundation, 1946.

This short pamphlet sets forth methods of procedural research to assist professional organizations in administering their programs. Examples are drawn from the experiences of various groups particularly the American Library Association. Administrators in professional fields, especially those called on to make surveys, will find this a valuable aid.

RECENT PROGRESS IN HORMONE RESEARCH. Proceedings of the Laurentian Hormone Conference. Volume I. Edited by *Gregory Pincus*, D.Sc., Research Professor of Physiology, Tufts Medical School. Cloth. Pp. 399. Price, $7.50. New York: Academic Press, Inc., Publishers, 1947.

In this volume are collected the papers presented by a group of the leading investigators in the field of endocrinology at a Hormone Conference of the A.A.A.S. A valuable addition is the inclusion of the discussions which often are as illuminating as the formal chapters. There is considerable new material, which has not been published elsewhere.

Chapters of particular interest to physiatrists are those by Nachmansohn on the Role of Acetylcholine in the Mechanism of Nerve Activity; The Effect of Hormones on Osteogenesis in Man by Albright, and the series of papers on the adrenal hormones.

All physicians interested in endocrinology will want this in their reference library.

REHABILITATION THROUGH BETTER NUTRITION. By *Tom Spies*, M.D., from the Department of Internal Medicine, University of Cincinnati College of Medicine. Cloth. Price, $4.50. Pp. 83, with 50 illustrations and graphs. Philadelphia, London: W. B. Saunders Co., 1947.

The term rehabilitation has become so firmly associated with physical medicine during the recent years that its application to nutrition is almost startling. In the opening paragraph Dr. Spies sets forth his theme thus "more people are starving today than ever before in the history of the world. We are face to face with the grim task of reconditioning and refitting, physically and mentally, men, women, and children whose tissues are injured by poor nutrition."

Dr. Spies has been studying nutrition intensely for seventeen years with particular emphasis on the vitamin B complex. He knows as much about this particular vitamin as anyone else in the world; the seven pages of references of his own work and that with which he collaborated will partly attest to this. His position in this field is authoritative and unsurpassed.

This short monograph is the report of his work through these years. The famous Birmingham study of 893 patients is analyzed not in the typical detailed method but in a more general and interesting manner. Paragraphs on the various deficiencies such as niacin, thiamine, riboflavin and others are considered so as to make a diagnosis possible. A great deal of information is presented in relatively few words. He justifies the use of his term "nutritive failure" and shows ways and means of correcting the disorder.

This is not a textbook either on nutrition or vitamins but the expression from a physician whose experience can properly correlate the part they exert in normal and abnormal physiology. The progress he has achieved thus far and the hopes that may be entertained for his efforts in the future should help obtain his goal of rehabilitation through nutrition.

HANDBOOK OF NEUROLOGICAL EXAMINATION AND CASE RECORDING. By *D. Denny-Brown*, M.D.; *J. Jackson Putnam*, Professor of Neurology, Harvard Medical School. Paper. Price, $1.75. Cambridge, Massachusetts: Harvard University Press. London: Geoffrey Cumberlege, Oxford University Press, 1946.

A pocket size book containing the more important methods for a neurologic examination. The booklet is published for senior medical students to help them establish a methodical manner for a diagnosis in this rather complicated and confusing field.

PHYSICAL MEDICINE ABSTRACTS

Prescription of Physical Medicine by the Internist. Arthur L. Watkins.

Ann. Int. Med. 26:569 (April) 1947.

Adequate and successful use of physical agents can be expected only when they are prescribed in a thoughtful and scientific manner. It is the duty, therefore, of physicians prescribing physical medicine to use similar accuracy and detail as when prescribing drugs. In both instances instructions are given to an intermediary highly skilled in technical matters, but untrained in diagnosis. Full advantage of the physical therapist's technical skill can be obtained only by indicating the nature of the condition to be treated and the specific effects to be expected from therapy. The choice of agents to be used should be determined by the physician and an intelligent selection can be achieved solely through knowledge of the actions of the various physical therapeutic measures. As a background for prescription writing it is therefore in order to consider briefly some of the known effects of physical agents on various tissues of the body. As physical agents act primarily from the exterior, it is logical to consider first their effect on the superficial structures.

An adequate prescription should include: a working diagnosis; specific instructions as to choice of agents; indication of effects to be produced; statement of duration and frequency of treatment. Such a prescription can be written by the internist with some knowledge of the scientific basis of physical medicine.

Spontaneous Regeneration of Severed Nerves. Lewis J. Pollock; James G. Golseth; Frank Mayfield; Alex. J. Arieff; Erich Liebert, and Y. T. Oester.

J. A. M. A. 134:330 (May 24) 1947.

It has long been known by physiologists and anatomists that it is more difficult to prevent regeneration of a severed nerve or one from which a large segment may have been removed than to obtain regeneration of the severed nerve after suture. This has been found to be true whatever measures may have been taken to prevent regeneration.

In 12 cases the chronaxia was less than 15 milliseconds. Of these, 3 were cases of injury to the peroneal nerve; 4 radial; 1 tibial, and 4 ulnar.

Although at operation the ends of severed nerves may have been separated by gaps of some distance, prior to surgical intervention there was evidence that nerve fibers had found their way into the distal segment.

Since it was found that the galvanic tetanus ratio of a completely denervated muscle remains 1.0 for as long as a muscle was observed at times for over a year, it is considered safe to conclude that a galvanic tetanus ratio of over 1.0 is indicative of some neurotization of a muscle.

At the time that gaps of varying lengths between ends of severed nerves have been found on operative intervention, there has been evidence that fibers had found their way to the distal segment. This evidence consisted of: in a few instances, a return of sensation; in a considerable number, a short chronaxia and response to faradic stimulation of muscle, and in most, a galvanic tetanus ratio of over 1.0. Histologic examination revealed the presence of neurofibrils in the distal segments of the severed nerve. Spontaneous regeneration, probably of insufficient degree to result in recovery of function, occurs to some extent in most instances of severed nerves.

Physiologic Basis for Therapeutic Trends in Neuromuscular Dysfunction. Norma M. Hajek, and Harry M. Hines.

J. Iowa M. Soc. 37:157 (April) 1947.

Research has been conducted in the laboratories of the State University of Iowa to evaluate the efficacy of postulated therapies for neuromuscular dysfunctions. This report defines the extent and summarizes the results of the experimentation and clinical observation.

The plan was to reproduce in laboratory animals by experimental procedures functional disorders of the neuromuscular system comparable to clinical states. The therapies most frequently employed for neuromuscular dysfunctions were classified as physical, nutritional, or drug.

In contrast to the negative results with drug and diet treatment, the response to physical therapy is encouraging. Massage had little effect on the rate and extent of atrophy but maintained a better functional condition in the affected muscles. Electrical stimulation served to lessen the weight decrement. The modality of effective treatment necessitated application of brief and frequent stimuli sufficiently intense to elicit maximal tension development in muscles treated under conditions of maximal load and stretch. The authors found that while excessive activity and fatigue did not prove detrimental to the over-all recovery from peripheral nerve injuries, they were without effect on the rate of nerve regeneration. A larger mass of muscle was preserved and maintained in a better functional state.

It is pointed out that the stimulus pattern which was found to be most effective for the retardation of atrophy in the muscles of animals was too painful to be tolerated by the unanesthetized animal or patient. Investigators at Northwestern University, however, have reported encouraging results with a stimulus pattern which can delay atrophy and yet be tolerated by the unanesthetized patient.

In reviewing the experimentation thus far, it might be assumed that drug therapy is temporarily beneficial in conditions of myotonia congenita, myasthenia gravis and some states of spasticity. Physical therapy in the form of heat, massage and electrical stimulation appears to offer the most satisfactory means of treating experimental conditions of neuromuscular dysfunction.

Physics in Medicine. F. L. Hopwood; J. Read; F. W. Spiers, and C. W. Wilson.

Brit. M. J. **4493**: (Feb. 15) 1947.

This is a summary of four papers read at the September meeting of the Hospital Physicists' Association. The discussion was prompted by the recent publication of an American volume, *Medical Physics*, which, by its comprehensive scope and list of contributors, suggested that physics played a far more important part in American than in British medicine. However, the wider service to medicine which physics can provide is recognized in a recent leading article in the *British Medical Journal* which states: "At present the application of physics to medicine is limited to radiology, the electrocardiograph, and the electroencephalograph in diagnosis, and the somewhat empirical use of various forms of radiant energy in treatment; but it is highly unlikely that these represent more than a fraction of the contribution physics might make to human biology." This medical opinion, which recognizes that the possibilities of physics in medicine are much wider than the present almost exclusive concentration on radiotherapy by roentgen and radium radiations, is widely held by hospital physicists. The most natural extension from this field would be the physics of diagnostic radiography, and of therapy by infra-red and ultraviolet radiations, and high-frequency currents, though there are probably many spheres of medical research in which physical measurement can play an important part.

To be fully effective the physics in a general hospital should be the responsibility of one physics department, directed by a physicist under the general control of the hospital committees.

In order to serve all departments, rather than the radiotherapy departments alone, commensurate staff and laboratory and workshop facilities would be necessary. A common defect in the organization of physics in a hospital is failure to ensure that the physicist spends his time on work of the calibre for which he is paid, by providing adequate clerical, laboratory and workshop assistance to cope with the mass of odd jobs that continually arise.

Research provides a worth-while stimulus and those permitted to do research work should have freedom in their choice of problems and in its development.

The large-scale physical developments of great promise in their application in medicine would be best served by a research institute, with a staff of specialists in the different technics involved. The x-ray industry should cooperate, so that the institute could also undertake research into the improvement of x-ray and associated equipment and any desirable standardization.

Surgical Management of Vascular Leg Ulcers. Howard C. Rees, and John G. Slevin.

Surgery **21**:575 (April) 1947.

Ulcers of the lower extremity are primarily surgical cases. Too often surgery is thought of only after the patient has been given long periods of local treatment. Too much is expected of local treatment, one form of medication after another being tried before surgery is suggested.

Skin temperature tests and fluorescein dye tests are especially helpful in those cases where ischemia and stasis appear together, as well as to determine the condition of circulation in the skin around the ulcer site. We have found the fluorescein dye test as dependable as either skin temperature or oscillometric determinations. Also, it gives more accurate information as to the level of arterial involvement and the character of capillary circulation in the skin.

Ten cubic centimeters of a 5 per cent intravenous solution of fluorescein dye and a mercury lamp make up the special equipment for this test. The lamp has a glass filter which excludes most of the light rays and transmits light only in the region of 3,600 angstrom units. The dye is slowly injected intravenously. In fifteen to twenty seconds, depending on the speed of the patient's circulation, all areas exposed to the lamp rays where the circulation is good will show an intense golden green hue. It becomes more intense as more of the dye diffuses from the capillaries into the tissues. Cross scratches on the leg make fluorescent lines showing levels to which good circulation travels. Tissue with poor circulation shows as a dark purple color contrast.

The Role of Physical Therapy in Rheumatic Disease. Loring T. Swaim.

Practitioner **945**:185 (March) 1947.

The role of physical therapy in medicine is to build a healthy body: one which will overcome disease when present. There are three parts to this role when the disease is rheumatic in nature. First, to develop a sound body: one in which all the organs inside the trunk can and do function to their full capacity. Second, to restore the muscles to full tone. Third, to mobilize the joints to the greatest possible range of motion. The first will often stop the disease and will make the second and third possible, and by improved vitality help the healing of the damaged tissues of the muscles and joints.

The physical therapist must understand the nature of different kinds of rheumatism and arthritis in order to treat these conditions intelligently.

The role of physical therapy is an essential one in the treatment of all joint conditions, and the care with which this form of treatment is planned may determine the time element in the progress of these difficult cases. The protection, expert instruction and the grading of treatment by the physical therapist under the physician's direction, can and does shorten the period of illness. It may be the important factor in recovery.

Physical therapy has three essential things to consider. First, the patient's control of his own muscles; second, his discipline in required work; and third, his cooperation with someone else. He also learns to control his body for his own good and to relax at will. The massage and the exercises are an easy way to teach him things about his body which he has possibly never learned before. The lack of this care and undisciplined living may have been factors in the causation of his illness, and in any case it can be a deciding factor in his recovery. The lessons learned under the watchful eye of a conscientious and intelligent physical therapist may prevent the next attack.

Another point: except for the nurse, the physical therapist spends more time with the patient than anyone else, and often learns more of the home problems, the disappointments, the fears and the frustrations of her patient. She has the golden opportunity to get over to her patient important lessons in living, cooperation and philosophy of life, if she is the right type. She can do much to help the physician by her intelligent understanding of the significance of the things she hears. The caring physician can learn much from such a physical therapist and can do much to encourage the patient to work for the things he needs to have: a robust body, a peaceful mind and a faith. The patient must be looked on as a whole individual and treated as such.

The "Costoclavicular Syndrome." E. D. Telford, and S. Mottershead.

Brit. M. J. 4497:325 (March 15) 1947.

While the symptoms which may arise from pressure on the neurovascular bundle as it passes from the thoracic inlet to the arm, although many and varied, are well known and easily recognizable, there is no general agreement on either the site or the mechanics of the compression. There is no doubt that earlier writings have over-simplified the position, and only in recent years does it seems to have been realized that there is no one cause of pressure common to all cases.

The present study is based on: (1) the observations at 120 operations undertaken for the relief of pressure on the neurovascular bundle of the arm; (2) examination of the effects of posture of the shoulder girdle on the radial pulse in a series of 120 medical students; (3) the evidence obtained by dissection of 30 bodies.

An account is given of the findings in 120 operations and 30 dissections, with observations on 120 students. No one mechanical cause can explain all cases. Damage by pressure of the clavicle cannot happen in pure depression of the shoulder, but is a likely event in retraction and abduction if cervical rib or abnormal first rib be present. These cases will probably show whole symptoms is the hanging up of the plexus on a cervical rib or other mechanical obstacle. These cases are likely to show lowest trunk symptoms. The phenomenon of alteration in the radial pulse on movements of the shoulder is due to causes distal to the clavicle. It has nothing to do with the costoclavicular syndrome.

Physical Medicine in Traumatic Injuries. George G. Deaver.

New York State J. Med. 47:847 (April 15) 1947.

The various forms of therapy included in physical medicine are physical therapy, occupational therapy and rehabilitation. Physical therapy deals with the management of disease by means of physical agents such as light, heat, cold, water, electricity and mechanical agents. Occupational therapy includes the use of the arts and crafts, dramatics, music and recreational activities for functional and diversional treatemnt. Physical rehabilitation includes reconditioning activities and and prepares the patient for the activities essential for daily living and working.

The Physiology of Refrigeration Anesthesia. P. C. Lund.

Manitoba M. A. Rev. 27:141 (March) 1947.

Allen the chief pioneer of refrigeration anesthesia has shown that cold can be preservative as well as destructive of life and that the resistance of life to cold generally diminishes as the zoological scale is ascended. The injurious effects of cold are governed by factors such as: degree of cold, duration of cold, hydration of the tissue involved and supercooling. Supercooling is a property of protoplasm which permits of chilling to several degrees below the true freezing point without ice formation.

There is much misconception among members of the medical profession in regard to the effects of cold applied locally to the living human organism. This is largely due to the loose manner in which the terms "refrigeration," "cooling" and "freezing" are used in the medical literature.

Crymotherapy is defined as the therapeutic use of cold. Refrigeration is usually defined as the reduction of the temperature of the surface of a tissue to 0 to 10 C. The term "cooling" is used for reduction of temperatures from the normal to any level above 10 C. Freezing is the reduction of temperatures of tissues to such a level that the intercellular and intracellular water freezes. This usually occurs at —1 to —20 C.

At the present time refrigeration is utilized in the field of medicine for two distinct different purposes. First, to produce anaesthesia, usually in combination with a tourniquet, for certain amputations. Second, to enable survival of anoxemic tissue. This is accomplished by lowering the metabolism of the tissues which have a deficient blood supply and so keep them alive while a collateral circulation develops.